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FLOATING DRYDOCKS—THEIR MILITARY POSSIBILITIES AND VALUE.

BY REAR ADMIRAL JOHN D. FORD, U. S. NAVY.

A modern drydock, like a battleship or ocean greyhound, is a development, and its successful construction requires extended study, careful design and good workmanship. In fact, it is an easier matter to construct a battleship than a dock, and no nation ought to be more appreciative of this fact than the United States.

THE DEVELOPMENT OF THE DRYDOCK.

In early days, when man's weapons of war were spears and clubs, his war fleet probably consisted of canoes. Even these small boats had to be hauled on shore at times to be repaired or caulked with the simple stone or wooden tools of that age. After the canoe or dug-out had been dragged far enough upon the beach to permit repairs to be effected between the tides, the boat was again launched, and this constituted the genesis of the science that is now practiced of docking the largest of vessels.

As man's necessities increased or his desire to travel became more intense, the canoe developed into the galley, and the galley

into the sailing ship. There were successive improvements which finally brought about the naval and merchant ships that now traverse the ocean. The sea craft of the succeeding centuries thus became too unwieldy to be dragged on the sandy beach for repairs, and it became necessary to lay down inclined ways up which the vessel could be more readily hauled from the water. Then came the excavation with some crude form of gate or caisson for controlling both the egress and ingress of water to the dock.

As there is an innate desire upon the part of man to have his works endure, it was not long before an attempt was made to strengthen the walls and base of the excavation, so that the basin or dock could not be destroyed by heavy rains, internal springs, or the natural tendency of the sides to cave in.

It thus came about that the walls of the drydock were constructed of brick, wood, or granite, each material undoubtedly being the most suitable for special conditions and purposes.

PARTICULAR CARE SHOULD BE EXERCISED IN LOCATING DRYDOCKS.

It is because so many docks are not suitably located that they are a source of much trouble and expense. If it could be understood by those contemplating the construction of docks that it would be economy to give more study and reflection in locating these structures more docks would yield dividends, and their serious impairment would be of less frequent occurrence. It is because some of the docks are constantly under repairs, due to being located in unsuitable places, that the cost of using them is so great. It can certainly be expected that the cost of maintaining the structures will be excessive unless the designers take into account the nature of the soil in which the excavation is made, the influence of the river currents, the annual downfall of rain in the vicinity, and many other factors of equal importance that must be considered in the determination of location.

It is often the case that all the factors that enter into the construction of a dock are not considered by those administrators upon whom devolve the responsibility of deciding upon the location of the structure. The ability to enter and leave the dock

with safety, the nature of the borings of the land in the vicinity, the proximity to manufacturing and terminal facilities, nearness to the sea, climate, and even geographical reasons are elements that must be considered as having an important influence in determining the future usefulness of the dock for military purposes.

Unless the opinion of experienced experts is given more weight than that accorded individuals who have only casually taken up the question, it will be found that the expense of constructing docks will be much greater than anticipated. It is because there is a lack of appreciation of the knowledge and experience required to design and construct a dock that we find that some of the structures are barely completed before the fact is evident that the dock is too short, too narrow, too shoal on the sill, or is insufficiently piled; and thus, while primarily intended for large ships, it is only capable of being used by ships of medium size.

A brief history of the docks now in course of construction at several naval stations ought to show conclusively that it would be wise policy to appoint a board of experts composed of men within and without the service whose sole duty it should be to investigate and report upon the character, location, size and number of docks necessary for naval purposes.

THE FLOATING DRYDOCK.

It would seem incredible that there should not be suitable places in every harbor of good size for the location of a permanent drydock. From various causes, however, there are harbors where there are no suitable places, and, as a consequence, there has been invented the floating drydock, which can be built in convenient places and towed to the place where it could be used. In fact, much more can be done with such a dock. The dock can be towed to the ship in distress, and, after the disabled vessel has been placed on the ways of the dock, the ship and dock could be towed to some sheltered harbor, where repairs extending over months can be effected. The fact that floating docks are found in all parts of the world shows that it is not a great feat to tow such structures even thousands of miles.

VARIOUS COMPARTMENTS OF THE FLOATING DOCK CAN BE USED AS A REPAIR SHOP.

Floating drydocks have been so improved that they have grown from the crude wooden affairs of the seventeenth century, mere wooden boxes with side walls and a pump, to the mammoth steel structures that will safely lift a battleship of 15,000 tons. Further development can be expected, and therefore it ought to be apparent to the naval engineer and architect that the next advance should be in the direction of converting some of the side-wall compartments into workshops, thus permitting many and even important repairs to be made with the mechanical resources of the dock. By thus utilizing the side compartments of the structure it will be possible, by towing such a dock near the base of operations, to keep the fighting ships much longer on the blockading line, since long trips to home ports might thus be avoided.

One of the heavy expenses incurred in constructing and maintaining every form of dock is the expense of installation of machinery that is seldom used. While the vessel is in the dock, or the structure unused, the pumping power of course lies idle. As a matter of fact, the engines, pumps and boilers are used but a few days each month. By utilizing the pumping plants connected with the dock for the operation of workshop tools, repairs could be cheapened as well as hastened. It is well within the range of probability that a ship entering such a dock might be supplied with light, cheap power and distilled water from the resources of the dock itself. In fact, such a structure might be regarded as a floating repair hulk as well as a floating dock.

FLOATING DRYDOCKS A NECESSITY FOR EACH DISTANT NAVAL STATION.

With the great extent of coast line—Atlantic, Pacific, gulf and insular—that we must now defend, we should be possessed of at least four docks that could be towed and anchored in sheltered places in close touch with the probable scene of operation of our fleets. With such auxiliaries the hulls of our war vessels could be constantly kept clean, their higher speed maintained, and repairs made that would lessen the tendency for the ships to

leave their station in time of war or when important fleet maneuvers were being conducted. When our great extent of coast line is considered, it must be realized that we are very deficient in docking facilities in many localities where it is essential that we should possess such auxiliaries.

As the scene of future naval operations upon the part of this country may be in some unexpected quarter, we should provide several floating docks, for their military value will be conclusively proved in the next naval war.

THE COST OF A FLOATING DRYDOCK.

The cost and management of a floating drydock is about one-half the cost of a graving dock when the latter is made in solid ground and under the most favorable conditions. The graving dock requires from three to six years to complete even under the most favorable conditions. It is necessarily located in a fixed place where it is subject to impairment from leaks and floods. With such a dock the damaged vessel, no matter how crippled her condition, must be taken to the docking structure for repairs.

In the case of the floating drydock the time of construction ought not to exceed from two to three years. Such a dock can be built anywhere, and even the several sections might be built at different places, and thus the speed construction of the structure hastened in case of necessity. The appropriation available for the self-docking, steel, floating drydock for the Cavite naval station is $1,225,000. In reference to this dock it is stated:

"It is the declared and acknowledged intention and meaning to provide and secure a complete and substantial self-docking, floating, steel drydock of American manufacture suitable for docking all of the present and projected ships of the United States Navy, for which appropriations have been made, located and installed in complete and perfect working order, together with all the moorings, wharves, approaches, accessories and appurtenances necessary for its perfect, complete and convenient operation and maintenance."

The cost of a stone dock capable of doing this work would be certainly three to four times the appropriation that has been authorized for the construction of the self-docking steel structure.

CARE AND MANAGEMENT.

Under competent management, floating drydocks can be moved about as safely as large hulks that are without motive power. The care and management of such docks is no more exacting than that required in operating large vessels where engineering experience and skill must be possessed. These docks have been towed in safety to all parts of the world. Where sections of the dock have been lost the cause can be traced either to terrible gales experienced, in which ships were also lost, or to carelessness upon the part of those in charge of the tow.

SANITARY ADVANTAGES OF A FLOATING DRYDOCK.

As the floating dock lifts the vessel above the surface of the water, the ship's company and the workmen have better conditions as to light, air and atmospheric surroundings than they could secure in a vessel docked in the regular manner. The graving dock is damp and dingy, and it cannot conduce to the health of the crew to inhale gases from the decomposition of the grass and scrapings from the ship's side.

There is no doubt but that the health of the men is seriously affected when a ship remains in a graving dock for some weeks, and the superiority of the floating dock is thus a matter of military importance. The fact should also not be forgotten that the graving docks are surrounded by machine shops in which there are hundreds if not thousands of workmen employed, and that these artisans and laborers sometimes smuggle spirituous liquor on board the ship in dock. Where it is only desired to clean and paint the vessel, a floating dock remote from such demoralizing influences would add greatly to the preservation of discipline and to the maintenance of good health.

FLOATING DRY DOCK AT THE NAVAL STATION, NEW ORLEANS, LA.

In view of the necessity of increasing the capabilities and of adding to the military value of our naval station on the Mississippi River, the Congress authorized the construction of a self-docking steel dock to be located opposite the City of

New Orleans. The swift current of that river and the nature and character of the soil forbade the making of an excavation for a suitable graving doek. Military necessities thus compelled the construction of a floating type of dock for that station. It could hardly be expected that any endurance could be secured for a graving dock built on soil where it would be almost impossible to secure a proper foundation, and where the dock, after completion, might be seriously injured by the floods that are experienced in that vicinity.

Another advantage of the floating dock at that point was its remoteness from the sea where there was no possibility of its being destroyed by an enemy. Its proximity to the city of New Orleans insures a supply of stores and material that may be requisite for efficient repairs. At this port there are also available thousands of skilled mechanics who can be employed in times of emergency. The shipping industry of that city is also of great extent, and thus in times of emergency men who have aptitude for sea life and who have had experience at sea might be recruited for the ships that were short in their complements. The proximity of this city to the coal fields of Alabama, and the cheapness with which coal can also be secured from Pennsylvania and Tennessee, make the port a desirable one for the establishment of a naval station.

This floating dock was built by the Maryland Steel Company, Sparrows Point, Maryland, in conformity with a circular issued to builders specifying the general character of a floating drydock for the U. S. Navy.

The dock was built from English plans and specifications that had been revised and modified by the Bureau of Yards and Docks, Navy Department. Before the contract was signed, particular attention was given to improvement in detail.

THE CONTRACT FOR THE DOCK.

The contract was signed April 10, 1899, the price being $810,000. The time allowed for completion was eighteen months, which time was afterwards extended to May 26, 1902. The principal causes for the delay were the difficulty experienced in

procuring material and the inability of the mechanics at Sparrows Point to continue work in rainy and severe weather upon a structure where shelter could not be secured.

The contract required that the dock should be built of mild steel of American manufacture, and of the best workmanship, all material and work to be inspected by an officer representing the Navy Department.

The contract required that the structure should be secured with two steel bridge booms connecting the dock with the shore by means of steel piers—one boom fixed near its bow and one secured to the stern. The booms are to be hinged both at the dock and at the pier ends so as to accommodate themselves to the sinking and raising of the dock.

The dock was to be capable of raising a ship of 15,000 tons to a height of six feet above the surface of the water, or sustaining a vessel of 18,000 tons with the deck of the dock awash. There was also required that the 15,000-ton vessel should be raised within 3½ hours from the time of entering the dock. This period was to include the time for mooring the ship, pumping out the dock and making all the lifting operations necessary for the proper securing of the ship. The dock was also to be supplied with winches, bollards, etc., and to be capable of docking any of its own pontoons.

CONSTRUCTION OF THE DOCK.

Immediately after the contract was signed Civil Engineer A. C. Cunningham, U. S. N., was detailed by the Department to superintend its construction. This officer remained on duty until the dock was officially accepted. Under his general direction detailed drawings were made, material ordered, excavations completed and the dock secured in place. The work on the dock was greatly facilitated by the use of gang punching machines, which spaced and punched the holes as evenly and equally as if templates had been used. The dock was floated October 5, 1901. Ten days later it left Sparrows Point in tow, and arrived at New Orleans, La., November 6, without mishap.

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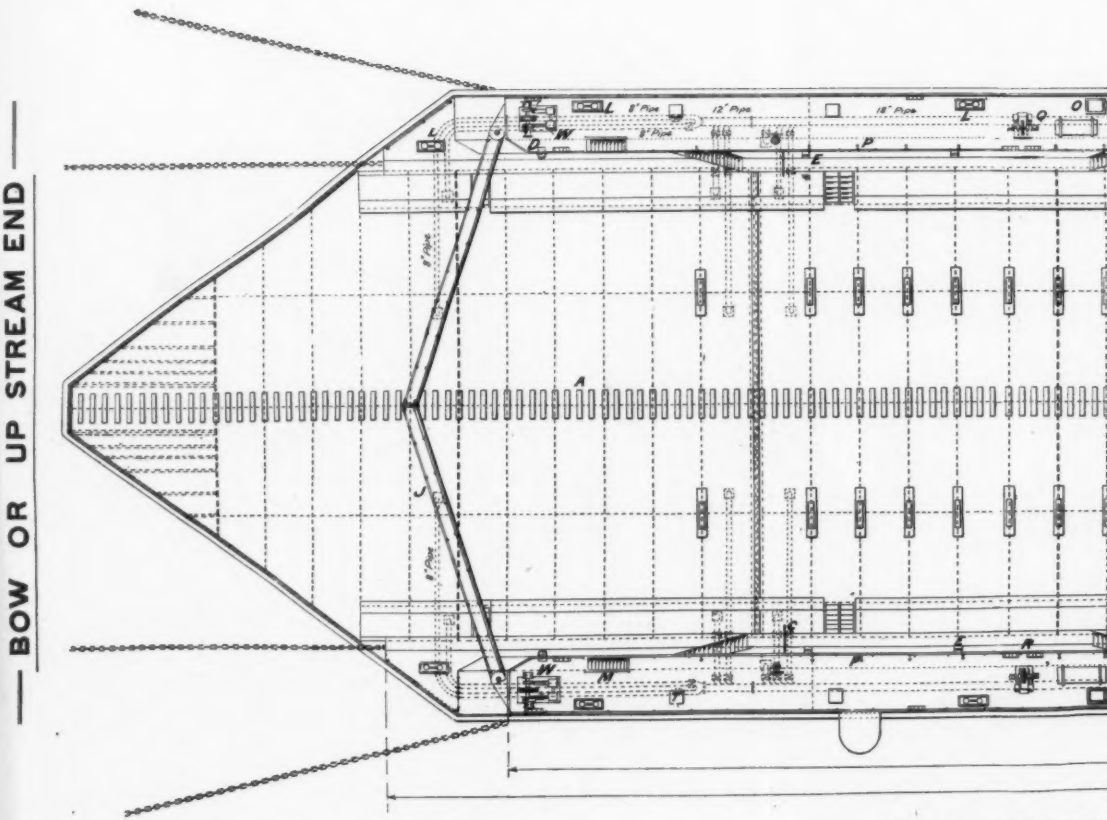
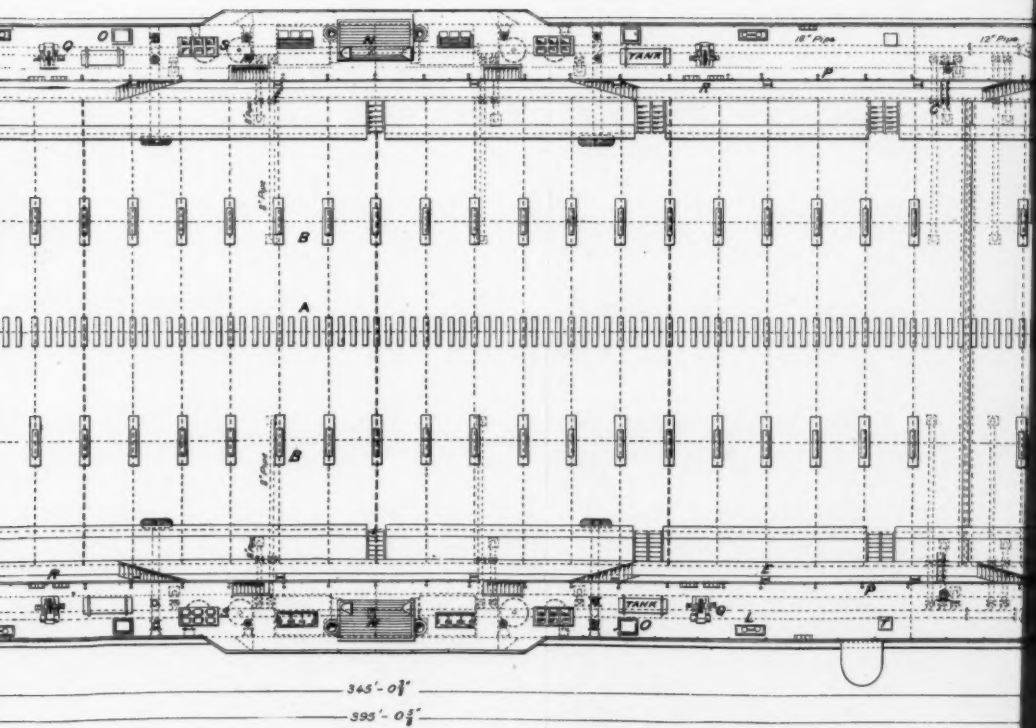


PLAN OF NEW

The connections for hinged bridges are shown on port side.



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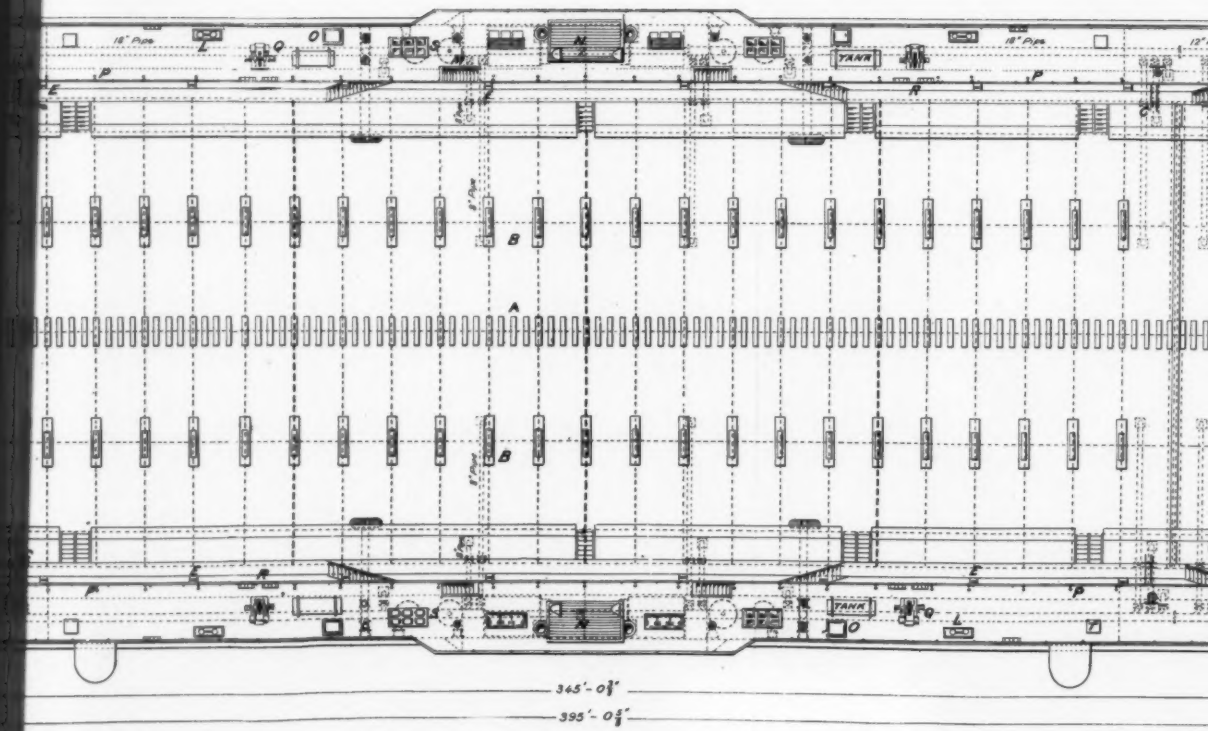
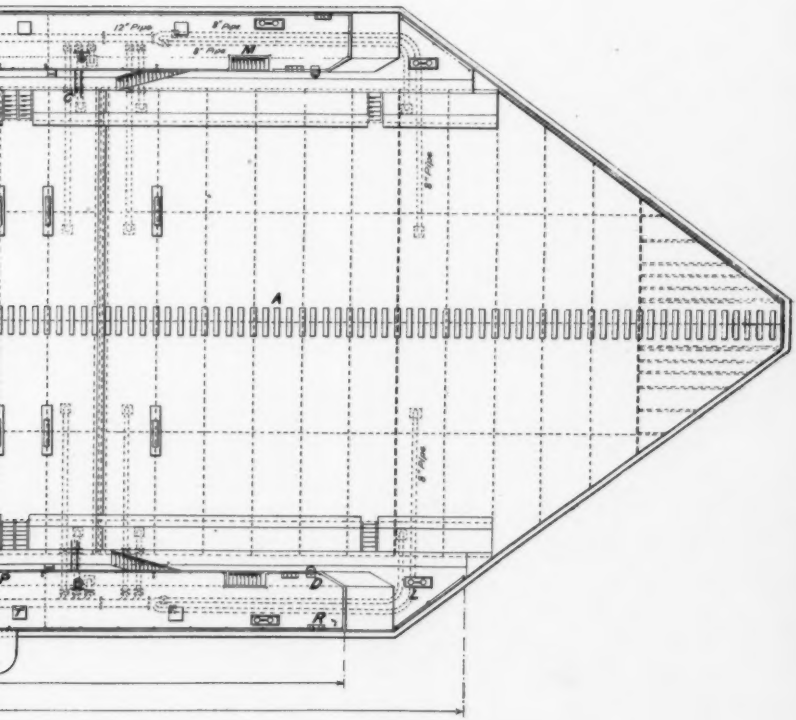
The bilge blocks shown o
timber sills and docking ke

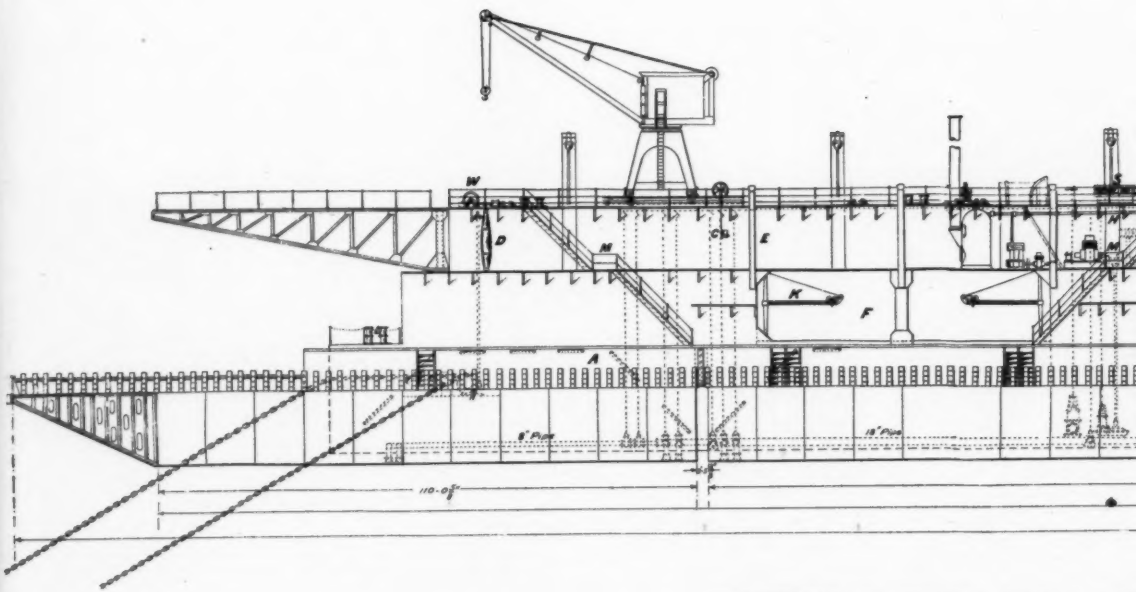


PLAN OF NEW ORLEANS STEEL FLOATING DRYDOCK.

The bilge blocks shown
timber sills and docking

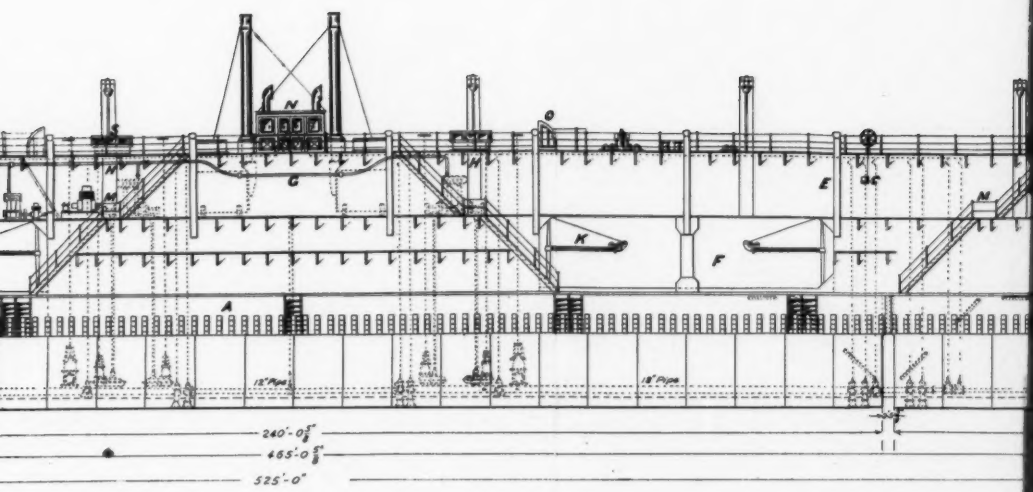


ge blocks shown on plan were replaced by an improved system of
ls and docking keel blocks.



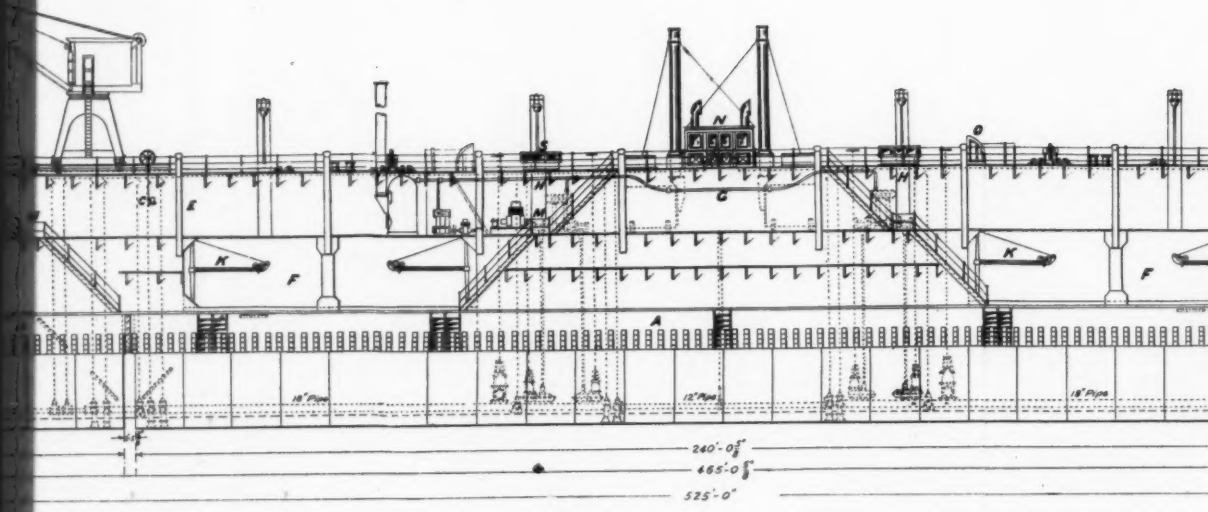
SECTIONAL ELEVATION, NE

The traveling cranes were omitted.
The bracketed ends have no lifting power.



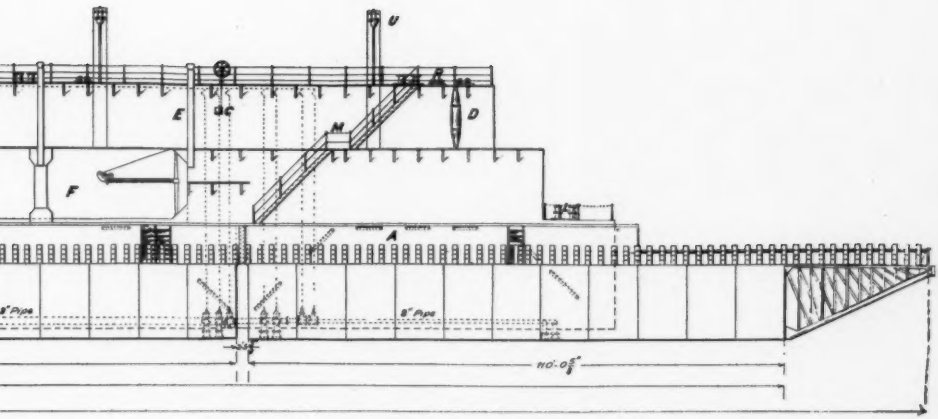
TION, NEW ORLEANS STEEL FLOATING DRYDOCK.

The flying gangway is shown open.
The pontoons were deepened two fee



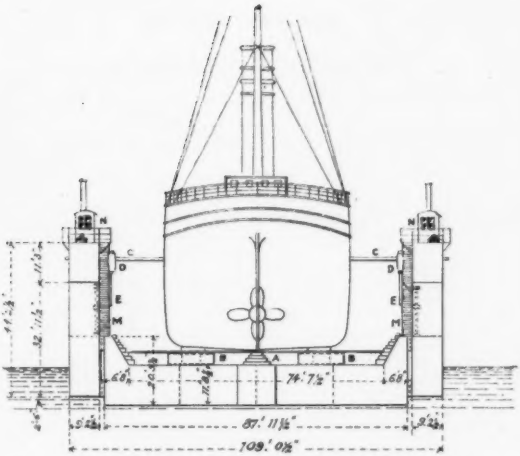
SECTIONAL ELEVATION, NEW ORLEANS STEEL FLOATING DRYDOCK

The flying
The ponto



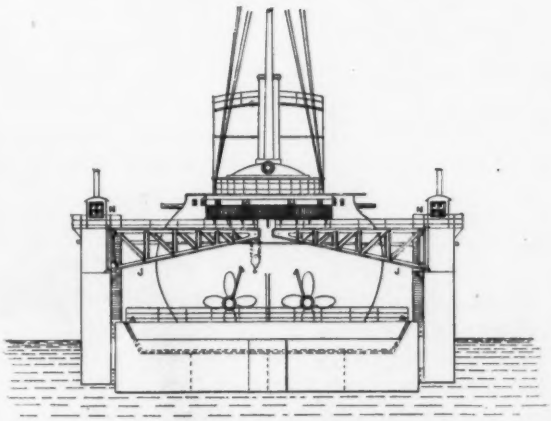
DRYDOCK.

The flying gangway is shown open.
The pontoons were deepened two feet in excess of depth shown on plain.



TRANSVERSE SECTION.

As Ordinary Floating Dock lifting Merchant Vessel.



END ELEVATION.

As Caisson Dock lifting Ironclad.

HAVANA STEEL FLOATING DRYDOCK.

GENERAL DIMENSIONS OF THE DOCK.

Length over all, feet	525
Breadth over all, feet and inches	126-2 7/16
between fenders on walls, feet	100
Maximum draught, feet	50
Depth over sills, feet	28
Length of walls, feet and inches	395- 4/8
Width of walls, feet and inches	12-1 1/2
Freeboard of walls, feet	28
sills, feet and inches	4-9
Number of pontoons	3
Length of middle pontoon, feet	242
end pontoon, feet and inches	141-1 4/8
Depth of pontoons, feet and inches	17-6
Clearance between walls and pontoons, feet	2
Number of watertight compartments in middle pontoon	16
each end pontoon	8
supporting bulkheads in middle, fore and aft	3
frames	26
bulkheads, athwartship	5
bulkheads, each end pontoon, fore and aft	3
athwartship	5
frames, fore and aft	9
Distance from center to center of frames, fore and aft, ft. and ins.	2-6
Outside plating, thickness, inch	4/8
Distance from center to center of rivets	Varies.
Diameter of rivets	Varies.
Number of keel blocks	209
Height of keel blocks, feet	4
Weight of dock, tons	6,122

THE PUMPING MACHINERY.

The pumping machinery is installed in the side-wall compartments. At the bottom of each wall are placed four centrifugal pumps which discharge directly outboard. The pumps are horizontal, with branch pipes leading through all the watertight compartments of the side walls and pontoons. Each pair of pumps is driven by a vertical, compound, non-condensing engine, which is installed in the central and upper compartments of each side wall.

Steam is furnished by four Babcock and Wilcox water-tube boilers, one boiler being provided for each engine. The steam piping is so arranged that any engine can take steam from any boiler. Each boiler, engine and pump is of standard size, thus

making it possible to have an interchangeability of parts in case of breakdowns. The main pumps are connected by vertical shafting and gearing to their respective engines. The engines are fitted with automatic flywheel governors, which are intended to maintain a regular speed of 300 revolutions per minute, no matter what the fluctuations of the water load may be.

DIMENSIONS OF MACHINERY.

The following are the principal dimensions of the compound, vertical pumping engines:

Number of engines	4
H.P. cylinder, diameter, inches	13
L.P. cylinder, diameter, inches	22
Stroke, inches	12
Main shaft, diameter, inches	4½
Vertical shaft, diameter, inches	3 5/16
Gearwheel, diameter, inches	6
Pumps, main, number	8
Pumps, horizontal centrifugal	8
Suction pipe, diameter, inches	16
Discharge pipe, diameter, inches	16
Revolutions, maximum	410
minimum	310
Capacity of each pump, gallons per minute	5,000
all pumps, gallons per minute	40,000

GENERAL DESCRIPTION OF BOILERS.

Steam is furnished by four Babcock and Wilcox cross-drum boilers. The casings are of steel lined with asbestos.

Number of boilers	4
tubes in each boiler	90
Length of tubes, feet	14
Diameter of tubes, inches	4
Grate surface, each boiler, square feet	33½
Total grate surface, square feet	133½
Heating surface, each boiler, square feet	1,356
all boilers, square feet	5,424
Hydrostatic pressure to which boilers were subjected, pounds	225
Working pressure of boilers, pounds	160
Drains: Diameter of main drain, inches	18
2d branches, inches	12
3d branches, inches	8

Worthington pumps are installed in each wall compartment for washing down and fire service.

OPERATION OF THE DOCK.

The whole dock is operated from a central station house on each side wall. In these stations levers are placed by means of which the valves are operated. Signals are arranged by means of which the position of every valve can be known at a glance. Each station is in direct communication with those in charge of the engine and fire rooms by means of speaking tubes, and thus the dockmaster has complete control of every pump and valve. The docking of the ship can thus be manipulated without the dockmaster leaving his central station. The dock is moored by four stud-link chain cables, to each of which are attached mushroom anchors. These anchors are handled by capstans connected to winches which are installed on the upper deck of the side walls. The dock is also connected to shore steel columns by two steel lattice booms, which are free to move in all directions to accommodate for the rise and fall in the river, which is subject to great fluctuations. These connections also permit the dock to be swung in toward the shore so that the structure need not be exposed to the strongest current of the river.

The side walls are provided with flying gangways, which are placed at the bow end of the dock, hinged so as to swing together. The side walls are fitted with platform and protecting hand rails to provide a means of passing from one section to the other. Convenient ladders and stairways are placed on the inside of the side walls to reach the upper decks from the pontoon deck. Light swinging hand cranes are provided on each gangway deck for handling material. There are also provided fair-leads and other appliances for handling the necessary lines required for docking the vessels.

IMPROVEMENTS IN THE ORIGINAL DESIGN OF THE NEW ORLEANS DOCK.

A general plan of the New Orleans dock accompanies this paper from which its general design and arrangement can be seen. A general plan of the Havana floating dock, which is of

the same general design, is also given. From a comparison of the two docks it will be seen that there are numerous improvements in the New Orleans dock, the principal one being the reduction in number of pontoons from five to three. Using fewer pontoons of greater length tends to produce a dock of much greater longitudinal stiffness by reducing the number of junctions in pontoons. Such a design also makes a more continuous structure, and thus there is a stiffening of the center pontoon, where the heaviest weight must be carried. The most important improvement made in the English design of the New Orleans dock was the deepening of the pontoons by two feet and the stiffening of their decks, so that blocking could be placed at any point. These requirements, besides giving greater freeboard to the deck of the dock and making it much stronger for working purposes, added greatly to its longitudinal stiffness, and without them it is doubtful if it would have passed a satisfactory test of inspection under the load of the *Illinois*.

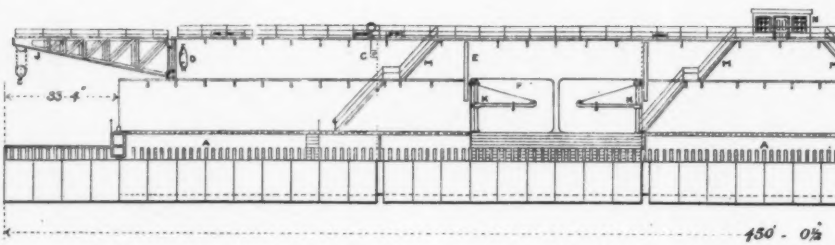
The new floating dock for the British Government at Bermuda was designed at the same time as the New Orleans dock and by the same English firm of designers. Had it not been for the Bureau of Yards and Docks requiring the deepening of the pontoons by two feet, the Bermuda dock would have exceeded the New Orleans dock in lifting capacity by several hundred tons.

DESIRABLE IMPROVEMENTS.

The New Orleans floating drydock has the greatest lifting capacity of any dock of its type. In workmanship, equipment and machinery, as well as in facility of operation, it is considered superior to any floating dock yet built. There are, however, some features about this dock where improvements could be made. Some of the objections are inherent to the type, and a few are not. For instance, the ends of the dock are made pointed, and the side walls are shorter than the dock and stepped back on the ends. While this construction lends to economy of material, it prevents the docking of a ship in the end of the dock, and tends to heavy strains in the side walls, if the unloaded end compartments of the pontoons are unduly pumped from.

A Keel blocks.
B Sliding bilge blocks.
C Mechanical self-centering side shores.
D Spring roller fender.
E Spring rubbing timber.
F Gangway passages.
G Caissons.

— ME



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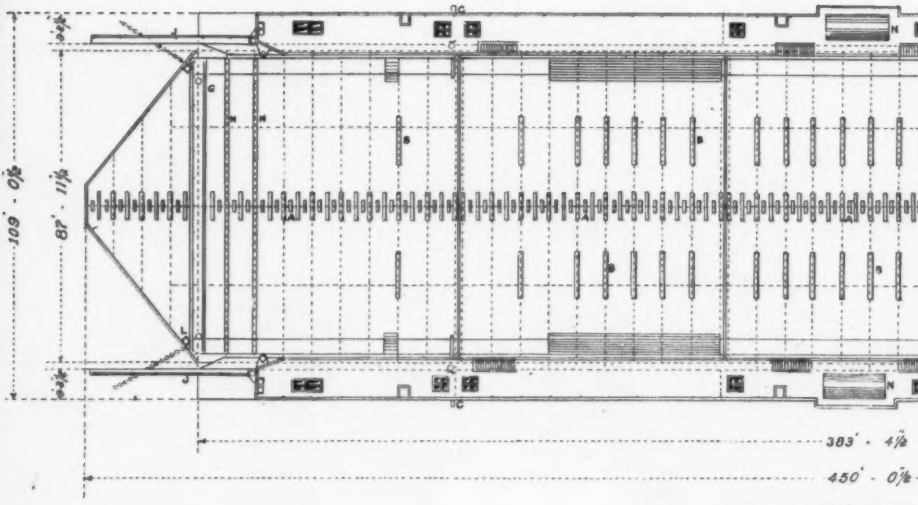


— PLAN

HAVANA STEEL FLOATIN

Lifting capacity, 10,000 tons.

After being broken in two, between the second and center pontoons in self do

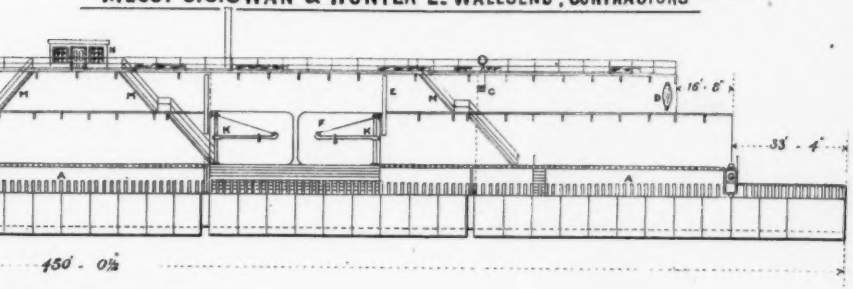
For battleships, the space enclosed by the altars and decks of pontoons is made watertight by
pontoons, thus forming a shallow graving dock. This feature was eliminat

H Grooves for caissons.
J Flying gangway and crane.

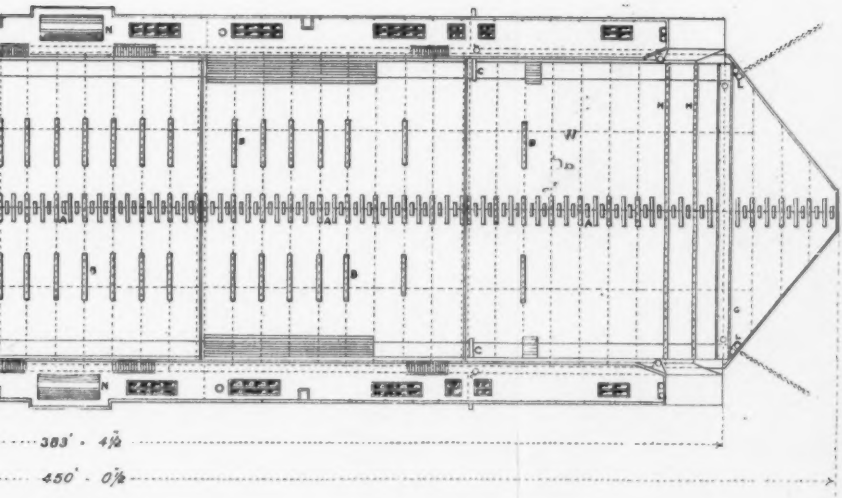
K Hand cranes.
L Mooring bollards and cables.

M Ladders.
N Valve house.

MESSRS C.S. SWAN & HUNTER LD WALLSEND, CONTRACTORS



IDE ELEVATION.



PLAN.

FLOATING DRYDOCK.

Towed from England to Havana.

toons in self docking, each section was separately towed to Pensacola.

le watertight by placing shallow caissons at the ends, and strips over the junctions of re was eliminated from the New Orleans dock by the Government.

The lower self-docking connections on this dock are always under water, unless the dock is specially heeled to bring them out. While this is not a serious matter in the fresh water at New Orleans, it becomes a vital objection in salt water, since even a little neglect will cause these joints to rust to an extent that self-docking might become a difficult matter. The side walls are self-docked by being canted out of water, and, as the inner edges are only raised about two feet clear, the space is not as great as it should be for convenient repairs.

TESTING THE DOCK.

After the arrival of the dock at New Orleans a special board, of which the writer was a member, composed of officers of the Navy, was detailed by the Honorable Secretary of the Navy for the purpose of examining and testing the dock. It was found to be impossible to maintain the proper depth of water at the site originally selected for the location of the dock, due to the shifting nature of the bottom of the river. The mechanical feature of the test was a complete success. During this official test the dock was lowered and raised several times, in order to test every feature of the structure. This was thus also possible to note the aptitude and ability of the people intrusted with its handling. It was soon demonstrated that there was not a sufficient depth of water to enable the dock to be lowered to its greatest working depth. Divers were sent down to examine the bottom. Wreckers were employed to remove the obstructions, and then it was found that the hindrance consisted of sunken and broken coal barges, lighters and other abandoned wreckage that had probably accumulated there from the time of the civil war. Around about the several wrecks there had accumulated considerable silt, thus reducing the depth of the water at the appointed site. In all the tests the dock performed satisfactorily. The crew in charge also demonstrated their ability to operate efficiently every auxiliary connected with the structure.

On December 30, 1901, the U. S. Navy collier *Sterling* was placed in the dock, and the vessel raised until the dock had two feet six inches freeboard. It was done in two hours. As the docking of the *Sterling* was merely a preliminary test, no at-

tempt was made to expedite the work, and yet it was done in two hours. The bottom of the *Sterling* was cleaned and painted while the vessel was in dock, after which the structure was lowered and the collier steamed out to her anchorage in the river. The following are the general dimensions of the collier *Sterling*:

Length over all, feet	275
Breadth of beam, feet	37
Draught, feet and inches	22–8
Displacement, tons	5,663

DOCKING THE BATTLESHIP *ILLINOIS*.

After the collier was undocked further efforts were made by the contractors to secure a greater depth of water under the structure at the site selected. As all such efforts were unavailing, the attempt was abandoned. On January 4 and 5 the top row of keel blocks was removed, and arrangements were made for docking the battleship *Illinois*.

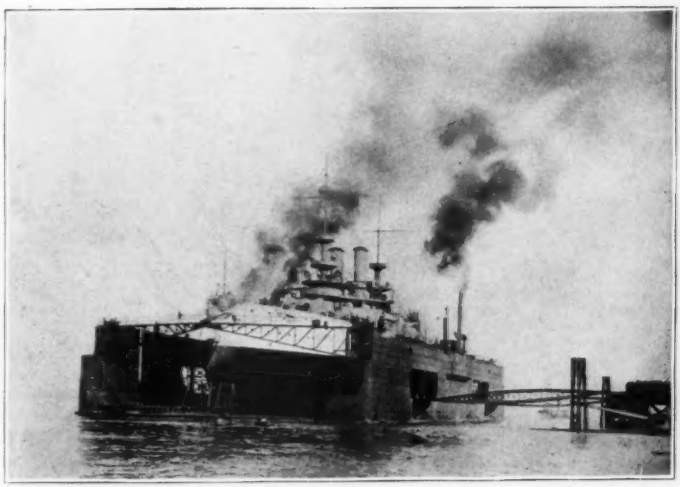
At 10·30 A. M. on January 6, 1902, the *Illinois*, with her crew, armament and stores on board, steamed up to the entrance of the dock, and two hours later she was placed within the structure. In exactly two hours she was raised to the amount required, which was forty minutes less time than allowed by the contract. The following are the general dimensions of the *Illinois*:

Length over all, feet	369
Beam, feet and inches	72–2½
Mean draught, feet and inches	24–1½
Displacement, tons	11,565

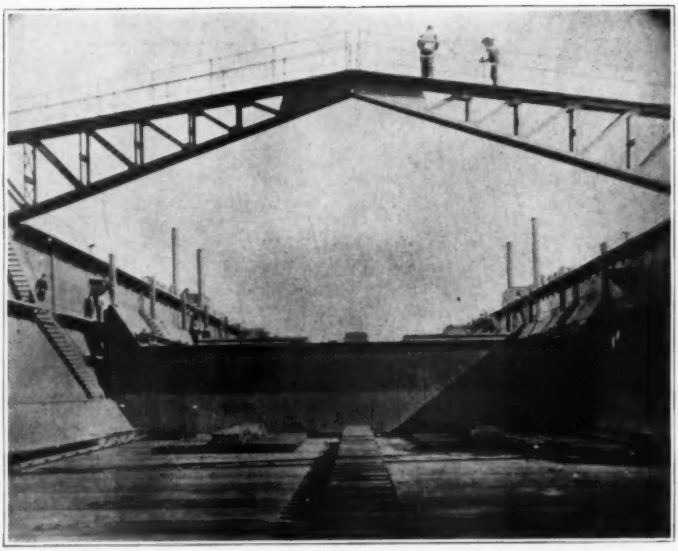
The *Illinois* remained in dock three days. She was undocked in less than three hours, after which the dock was carefully examined by the various members of the special board appointed to observe its working. No defects were discovered, and arrangements were then made to self-dock the various pontoons. This was also successfully accomplished. The dock was preliminarily accepted May 22, 1902.

EASY BEARING OF A VESSEL ON A FLOATING DOCK.

An interesting fact connected with the docking of the *Illinois* was the discovery that the cement in her double bottoms was not



DOCKING THE BATTLESHIP "ILLINOIS" IN THE FLOATING DRY DOCK AT THE U. S. NAVAL STATION, NEW ORLEANS, LA., JANUARY, 1902.



SELF-DOCKING THE MIDDLE PONTOON OF THE FLOATING DRY DOCK AT THE U. S. NAVAL STATION, NEW ORLEANS, LA.

cracked when the ship was lifted, thus showing that the vessel was carried very easily and without strain. It was also found that the keel blocks were neither marked nor dented, although the battleship was carried on the dock for over three days. The only thing found on the keel blocks was the paint that came from the bottom of the ship in contact with the blocks. It is thus of importance to note that there was neither cracking of the cement nor cutting of the blocks, proving that the tender bottom of a battleship can be carried on a well-designed floating dock with an evenly distributed pressure and without a tendency to strain.

SCOURING UNDER THE DOCK.

Preceding the docking of the *Illinois* great efforts were made by the contractor to dredge the located site to the necessary depth, so that the structure might be sunk to the full depth to which it was designed to be lowered. Although all wreckage had apparently been cleared away, the dredging seemed of no avail, as the site filled up as fast as material was removed.

Since the docking of the *Illinois*, a natural scour has set in under the dock, and the continuous flow of water under the structure has carried away all of the soft material, leaving a splendid foundation of clay at even a greater depth than is necessary for the extreme sinking of the dock even at the lowest stages of the tide. Several months' observation indicate that the scouring under the dock is permanent, and that no future trouble may be anticipated from lack of required depth for sinking the dock sufficient to enter any battleship that we possess.

DRIFT AND WRECKAGE.

Some difficulty was anticipated from floating and submerged wreckage, and yet but little trouble has been experienced in this direction. The greater part of the drifting material passes well clear of the structure by reason of the fact that the set of the current is on the side of the river opposite the dock. From time to time a diver, who forms part of the drydock's crew, makes an examination under the dock, so that assurance can be had that the dock is capable of being lowered to its maximum depth at early notice.

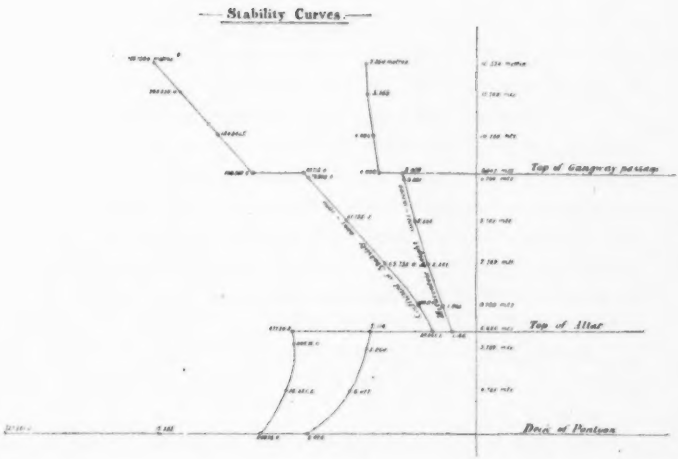
WORKSHOPS AND DOCKS ESSENTIAL TO THE EFFICIENCY OF EACH OTHER.

No other Government ship has been docked at New Orleans since the *Illinois* was at the station. The fact that the naval station at New Orleans does not contain well-appointed shops where extensive repairs can be effected has probably influenced the Department to some extent in not docking other battleships at that point. This condition emphasizes the important point that in the establishment of a naval station the progress of development should be so carried on that both docking facilities and workshops should be completed about the same time.

NAVAL DRYDOCKS ARE NECESSARY AUXILIARIES TO THE DEVELOPMENT OF OUR MERCHANT MARINE.

While the *Illinois* has been the only warship that has been docked at our naval station on the Mississippi, the structure has been extensively used by merchant shipping, and has proved a great boom to the maritime interests of the gulf. The small local floating docks at New Orleans are very old. None have a capacity exceeding 1,200 tons, so that there were practically no docking facilities at that port for oceangoing vessels before the arrival of the Navy floating dock. Since the maritime interests have been assured that docking can be successfully accomplished at the New Orleans station, the larger class of merchant vessels no longer hesitate to visit the port, since they now fully realize that in case of necessity the hulls can be readily cleaned and the most important repairs effected with the aid of the machine shops at New Orleans.

Standard rates for docking merchant ships have been established by authority of the Navy Department. By permitting the merchant marine to use the dock our coastwise trade is benefited. The efficiency of the dock is also maintained. It is non-use of every structure which brings about deterioration, and thus the Department is subserving national and commercial interests by using the dock as much as possible. Up to the present time the revenue received from docking fees has paid the current expense of the station, and has even provided a fair rate of interest on the original investment.


Stability Curves.
Top of Gangway passage
Top of Iltar
Deck of Pontoon

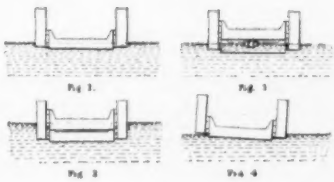


Fig 1.
Fig 2
Fig 3
Fig 4

A FLOATING DOCK FOR THE PHILIPPINES.

The successful and satisfactory docking of the battleship *Illinois* in the New Orleans self-docking structure has led the Congress to make an appropriation for another large floating drydock for the Philippine Islands. The Navy Department has recently issued a general specification for this dock. It is to be hoped that a number of firms will be induced to bid for the construction of this dock, so that general interest throughout the country can be manifested in this work, and thus the thought and energy of many be directed to making progressive improvements.

In the preparation of the specifications advantage has been taken of the information secured from New Orleans. Careful consideration has also been given to overcoming the defects experienced in other floating docks. The unfortunate accident by which the Havana dock was broken in two has likewise been the means of calling attention to certain inherent weaknesses that must be carefully considered. In greatly improving the efficiency, usefulness and endurance of the new dock for the Philippines, the accident to the Havana structure has not been altogether a serious loss.

The following are the principal dimensions of the dock for the Cavite naval station:

Length over all, feet	500
Width between fenders, feet	100
Height of side walls clear above the water, feet	8
Draught over four-feet keel blocks, feet	30
Lifting capacity, tons	16,000

The dock will be able actually to lift above the water, with the pontoon decks awash, 20,000 tons. The limited strains on material and the requirements for pumping are such that only gross carelessness or inefficiency can disable the dock. All self-docking connections will be installed above water, where they will not be liable to deterioration. For self-docking purposes, all under-water portions will be required to be raised at least five feet out of water. It is believed that a full compliance with the official requirements of the Navy Department will cause the

floating dock for the Philippines to stand as the future type for the Navy.

The dock proper is to be entirely completed and ready for test in every respect within twenty-seven months from date of contract.

THE MILITARY IMPORTANCE OF SUCH DOCKS.

Floating drydocks are certain to play an important part in future naval operations. The ease and rapidity with which they can be built, the ability to transfer them from port to port, and their adaptability to localities where graving docks cannot be constructed gives them an importance that can be no longer disregarded. Under existing conditions the dock question is of vital importance for keeping the fighting ships in a high state of efficiency. The problem of the dock, and particularly the possibilities of the self-docking drydock, is one that is worthy of the closest study of our naval strategists and administrators.

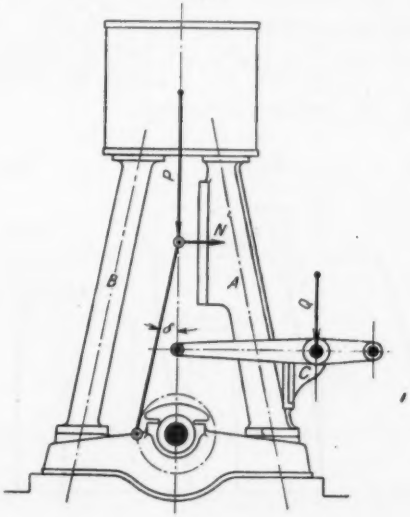
THE INVESTIGATION OF THE STRESSES ON FRAMES OF VERTICAL, INVERTED STEAM ENGINES.

By G. Schwarz, Oberürkheim–Stuttgart.

Published in the "Zeitschrift des Vereins Deutscher Ingenieure." Translated by John H. F. Meyer, Associate Member.

The force P on the piston of a vertical, inverted steam engine produces alternately a tensile and a crushing stress on the housing A and column B, respectively, shown in Fig. 1, while a bending stress is produced by the normal force N, equal to $P \tan \delta$ plus or minus the amount due to the mass of the swinging connecting rod transmitted through the crosshead. If an air pump is directly connected to the engine, then the weight Q

Fig. 1.

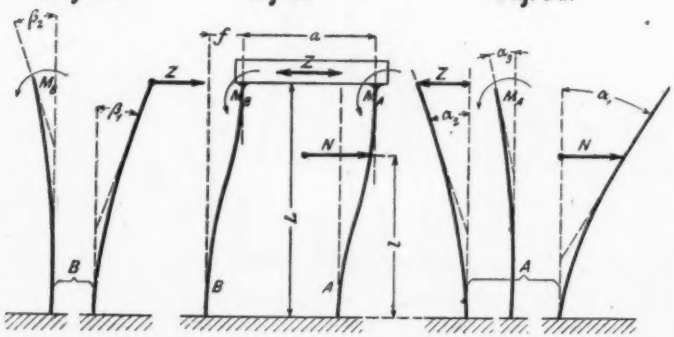


of the pump beams, piston and rod is acting upon the point C, and is producing an additional bending moment when the pump piston is on its upstroke, which has to be added to the moment obtained from the normal force N.

While now the deformation of A and B (generally called frames) by the tensile or compressive action of the force P is hardly noticeable, the deformation due to the bending action of forces N and Q can, under certain circumstances, become important as appearing in the more or less quiet working of the engine. The following examination of the bending stresses on the frames has been carried out with the assumption that the lower ends of the frames are fixed at the bedplate; the ends connected to the cylinder are treated as being fitted to a cross-bar so strong as not to undergo any change in shape by the action of any stress; further, that the frames have a vertical position and that their moments of inertia, J_A and J_B, are alike for every section over their entire length.

As shown in diagram (Fig. 2), the force N is applied at a distance l from the lower end and tends to turn the housing A to the right, but the force Z and the moment M_A turn it to the left, the latter two acting at a distance L from the lower end. Upon the column B is acting the force Z tending to turn the column to the right, while the moment M_B exerts an effort to turn it to the left, both at a distance L.

Fig. 2b. Fig. 2. Fig. 2a.



The angle β_1 of the tangent at the upper end of column B (due to the force Z) is, with E_B as a constant modulus of elasticity (see Fig. 2*b*),

$$\beta_1 = \frac{ZL^2}{2J_B E_B};$$

and the angle β_2 of the tangent (due to the bending moment M_B) at the same end,

$$\beta_2 = \frac{M_B L}{J_B E_B};$$

and as we have assumed a connecting crossbar which will not change its shape, or, what amounts to the same, if the upper ends of the frames are fixed to the cylinder, we must have

$$\beta_1 - \beta_2 = 0,$$

or

$$\left(\frac{ZL}{2} - M_B\right)\frac{L}{J_B E_B} = 0;$$

therefore,

$$M_B = \frac{ZL}{2}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Pursuing the same method as for column B, we obtain for the upper end of housing A the tangent angle of the elastic line under influence of the forces N, Z and M_A, (see Fig. 2*a*) to

$$a_1 = \frac{Nl^2}{2J_A E_A},$$

$$a_2 = \frac{ZL^2}{2J_A E_A},$$

$$a_3 = \frac{M_A L}{J_A E_A},$$

and from these, since

$$a_1 - a_2 - a_3 = 0,$$

we have

$$M_A = \frac{Nl^2}{2L} - \frac{ZL}{2} = \frac{Nl^2}{2L} - M_B. \quad . \quad . \quad . \quad . \quad (2)$$

The deflection f of the column B at the upper end is

$$f = \left(\frac{ZL^3}{3} - \frac{M_B L^2}{2}\right)\frac{1}{J_B E_B} = \frac{ZL^3}{12 J_B E_B}. \quad . \quad . \quad . \quad (3)$$

Again, from the assumed unchangeable connection at the top ends, the deflection f of the upper end of the housing A must be equal to f that of column B, therefore,

$$f=\frac{1}{J_A E_A}\left[\frac{Nl^3}{3}+\frac{Nl^2}{2}(L-l)-\frac{ZL^3}{3}-\frac{N}{2}\frac{Ll^2}{2}+\frac{ZL^3}{4}\right]=\frac{ZL^3}{12J_B E_B}.$$

By transforming the above we obtain

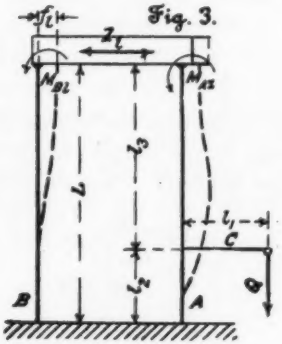
$$\frac{N}{J_A E_A}\left(\frac{l^2 L}{4}-\frac{l^3}{6}\right)=\frac{ZL^3}{12}\left(\frac{1}{J_A E_A}+\frac{1}{J_B E_B}\right). \quad . \quad . \quad (3a)$$

and further

$$Z=\frac{J_B E_B N(3l^2 L-2l^3)}{(J_A E_A+J_B E_B)L^3}. \quad . \quad . \quad . \quad . \quad . \quad (4)$$

From this equation the amount of M_B and M_A are found by inserting the value of Z in equations (1) and (2).

Fig. 3.



If an air pump is connected to the housing A, as before mentioned, and Q are the weights to deal with, we find again (see Fig. 3) from the notation of Fig. 3, and the former reasoning

$$M_{Bl}=\frac{Z_l L}{2},$$

$$M_{Al}=\frac{Q l_1 l_2}{2}-\frac{Z_l L}{2},$$

and the deflection

$$f_l = \frac{Z_l L^3}{12 J_B E_B} = \frac{1}{J_A E_A}\left[Q l_1\left(\frac{l_2^2}{2} + l_2 l_3\right) - \frac{Z_l L^3}{3} - \frac{M_{Al} L^2}{2}\right].$$

Inserting the value of M_{Al} in this equation and transforming the equation, we find

$$\frac{Q l_1}{J_A E_A}\left(\frac{l_2^2}{2} + l_2 l_3 - \frac{l_2 L}{3}\right) = \frac{Z_l L^3}{12}\left(\frac{1}{J_A E_A} + \frac{1}{J_B E_B}\right),$$

and for Z_l is obtained

$$Z_l = \frac{Q l_1}{L^3}(6 l_2^2 + 12 l_2 l_3 - 6 l_2 L)\frac{J_B E_B}{J_A E_A + J_B E_B} \quad . \quad . \quad . \quad (5)$$

From equation (5) it appears that the bending moment of the frames for a given Q and l_1 is a maximum if $l_2 = l_3 = \frac{L}{2}$, and that this bending moment is 0 if $l_2 = 0$, or $l_2 = L$. But aside from the point that the assumption of absolute rigidity of connection is not strictly accomplished, no designer will ever locate the point C at the weakest place of the respective frame.

Thus, for example,

$N = 1400$ kg.; $Q = 2500$ kg.
$l = 100$ cm.; $l_1 = 35$ cm.; $l_2 = 40$ cm.; $l_3 = 120$ cm.
$L = 160$ cm.
$J_A = 9000$ cm^4.; $J_B = 7000$ cm^4.
$E_A = E_B = 1000000$.

Substituting these values in equation (4) the force Z will be

$$Z = \frac{7000 \times 1400(3 \times 160 \times 100^2 - 2 \times 100^3)}{(9000 + 7000) \times 160^3} = 420 \text{ kg.};$$

and from this with equation (1),

$$M_B = \frac{420 \times 160}{2} \text{ cm. kg.} = 33600 \text{ cm. kg.},$$

and with equation (2)

$$M_A = \frac{1400 \times 100^2}{2 \times 160} - 33600 = 10150 \text{ cm. kg.}$$

The deflection at the upper end of the frames is, according to equation (3),

$$f = \frac{420 \times 160^3}{12 \times 7000 \times 1000000} = 0.0205 \text{ cm.} = 0.205 \text{ mm.}$$

The tensile force Z_l becomes with equation (5),

$$Z_l = \frac{2500 \times 35}{160^3}(6 \times 40^2 + 12 \times 40 \times 120 - 6 \times 40 \times 160)\frac{7000}{7000 \times 9000}$$

$$Z_l = 270 \text{ kg.},$$

therefore,

$$M_{Bl} = \frac{270 \times 160}{2} = 21600 \text{ cm. kg.},$$

and

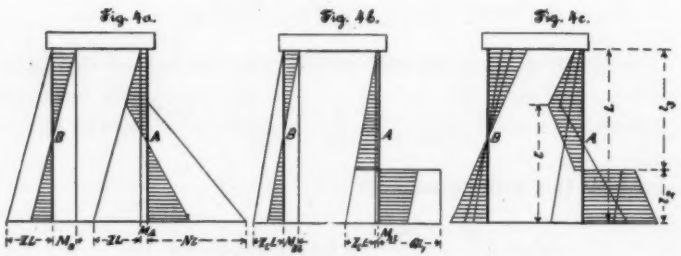
$$M_{Al} = \frac{2500 \times 35 \times 40}{160} - 21600 = 875 \text{ cm. kg.}$$

The deflection f_l will be

$$f_l = \frac{270 \times 160^3}{12 \times 7000 \times 1000000} = 0.0132 \text{ cm.} = 0.132 \text{ mm.}$$

and the maximum deflection of both,

$$f + f_l = 0.205 + 0.132 = 0.337 \text{ mm.}$$



In Figs. 4a to 4c are given the bending moments as they appear over the whole length of the frames; Fig. 4a and Fig. 4b

give the moments of the normal force N and the weight Q, while Fig. 4c gives the sum of these moments.

If column B is of such form, or is so secured, as to allow of considering it as being hinged at each end, while housing A is fastened to the bedplate and to the cylinder as described before, we have, as shown in Fig. 5,

$$\frac{1}{J_A E_A}\left(\frac{Nl^2}{2} - Z_B a L\right) = 0.$$

$$Z_B = \frac{Nl^2}{2aL} \quad \ldots\ldots\ldots \quad (6)$$

The deflection f is in this case

$$f = \frac{1}{J_A E_A}\left[\frac{Nl^3}{3} + \frac{Nl^2}{2}(L-l) - \frac{Z_B a L^2}{2}\right] \quad \ldots \quad (7)$$

or, if for Z_B its value from equation (6) is placed in equation (7),

$$f = \frac{N}{J_A E_A}\left(\frac{l^2 L}{4} - \frac{l^3}{6}\right) \quad \ldots\ldots \quad (7a)$$

Fig. 5.

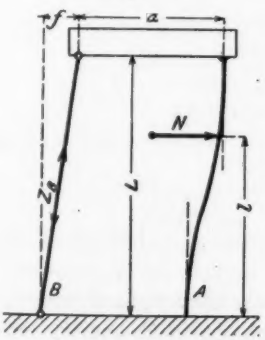
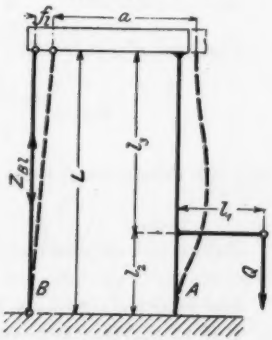


Fig. 6.



For the load Q referring to Fig. 6, we find as before

$$\frac{1}{J_A E_A}(Ql_1 l_2 - Z_{B1} a L) = 0,$$

or

$$Z_{Bl} = \frac{Ql_1 l_2}{aL} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

Further we find the deflection f_l with Z_{Bl} from equation (8),

$$f_l = \frac{Ql_1}{J_A E_A}\left(\frac{l_2^2}{2} + l_2 l_3 - \frac{l_2 L}{2}\right). \quad . \quad . \quad . \quad . \quad (9)$$

Using the same example as before, we find for the force Z_B from equation (6), if the length a of the crossbar is assumed to be 50 cm.,

$$Z_B = \frac{1400 \times 100^2}{2 \times 50 \times 160} = 876 \text{ kg.}$$

The greatest bending moment in the housing A at the lower end is

$$M = N_l - Z_B a = 1400 \times 100 - 876 \times 50 = 96200 \text{ cm. kg.},$$

and the deflection f of the housing A from equation (7a) is found by calculation,

$$f = \frac{1400}{9000 \times 1000000}\left(\frac{160 \times 100^2}{4} - \frac{100^3}{6}\right) = 0.0362 \text{ cm.} = 0.362 \text{ mm.}$$

The load Z_{Bl} is found from equation (8):

$$Z_{Bl} = \frac{2500 \times 35 \times 40}{50 \times 160} = 437 \text{ kg.},$$

and the deflection f_l from equation (9),

$$f_l = \frac{2500 \times 35}{9000 \times 1000000}\left(\frac{40^2}{2} + 40 \times 120 - \frac{40 \times 160}{2}\right) = 0.0233 \text{ cm.}$$

The forces Z_B and Z_{Bl} tend to decrease the length of housing A, but to increase the length of column B. If F_A and F_B represent the respective sections of the frames, the amount of decrease for A is equal to λ_A.

$$\lambda_A = \frac{Z_B L}{F_A E_A},$$

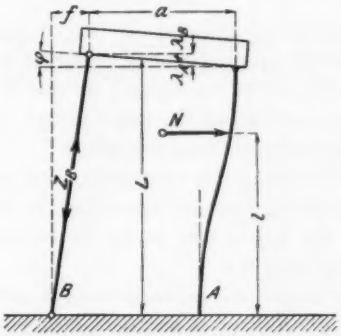
and the increase of B equal to λ_B,

$$\lambda_B = \frac{Z_B L}{F_B E_B}.$$

The assumed crossbar, in this case, has changed from a horizontal to an inclined position with an angle of inclination of $\varphi = \frac{\lambda_A + \lambda_B}{a}$.

According to Fig. 7, we have now

Fig. 7.



$$\frac{1}{J_A E_A}\left(\frac{Nl^2}{2} - Z_B a L\right) = \varphi = \frac{Z_B L}{a}\left(\frac{1}{F_A E_A} + \frac{1}{F_B E_B}\right),$$

and from this equation

$$Z_B = \frac{Nl^2 a F_A F_B E_B}{2L[a^2 F_A F_B E_B + J_A(F_A E_A + F_B E_B)]} \quad . \quad . \quad . \quad (10)$$

Retaining the same values of the former example and adding for housing A, the section $F_A = 140$ sq. cm. and $E_A = 1000000$, and for column B, to be now of wrought iron, the section $F_B = 70$ sq. cm.; $E_B = 2000000$, it follows from equation (10),

$$Z_B = \frac{1400 \times 100^2 \times 50 \times 140 + 70 \times 2000000}{2 \times 160[50^2 \times 140 \times 70 \times 2000000 + 9000(140 \times 1000000 + 70 \times 2000000)]}$$

$$Z_B = 832 \text{ kg}.$$

The deflection f in this case from equation (7)

$$f = \frac{1}{9000 \times 1000000}\left(\frac{1400 \times 100^3}{3} + \frac{1400 \times 100^2}{2}(160-100) - \frac{832 \times 50 \times 160^2}{2}\right)$$

$$f = 0.0396 \text{ cm.}$$

The quantities of λ_A and λ_B are hardly measurable, their sum being only

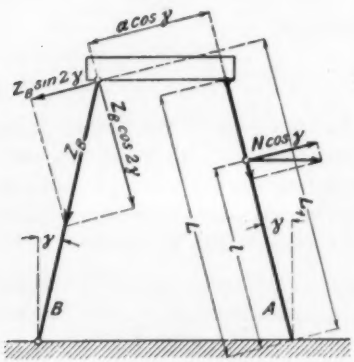
$$\lambda_A + \lambda_B = 832 \times 160\left(\frac{1}{140 \times 1000000} + \frac{1}{70 \times 2000000}\right) = 0.0019 \text{ cm.}$$

Therefore a very small difference in length between frames A and B is sufficient to produce a very remarkable change in the strain and deflection of the same, and by this is explained the fact, that with two engines of the same design and dimensions, one will generally be better than the other.

The length of column B is very often, in course of erection, purposely decreased to increase the strain in it. The amount of decrease and the result can easily be calculated from the equations we have deduced.

If the frames A and B are inclined to each other as shown in Fig. 8, the force N will act through its components upon the

Fig. 8.



frames, with $N\cos\gamma$ in normal direction and with $N\sin\gamma$ in direction of the axis A.

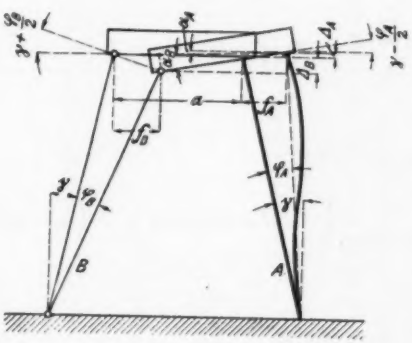
Z_B will be analyzed also into $Z_B \sin 2\gamma$ normal to A and $Z_B \cos 2\gamma$ parallel to A. By bending, the upper end of A is lifted the distance Δ_A, but at the same time the upper end of B is lowered the distance Δ_B.

The amount of the angles aA and aB is given by

$$aA = \frac{\Delta_A}{2};\quad aB = \frac{\Delta_B}{2}.$$

(See Fig. 8a.)

Fig. 8a.



While
$$\Delta_A = \frac{f_A \sin\left(\gamma - \frac{\varphi_A}{2}\right)}{\cos\left(\gamma - \frac{\varphi_A}{2}\right)}$$

and
$$\Delta_B = \frac{f_B \sin\left(\gamma + \frac{\varphi_B}{2}\right)}{\cos\left(\gamma + \frac{\varphi_B}{2}\right)}.$$

Due to the supposed deflection being very small, the angles

$$\frac{\varphi_A}{2} = \frac{f_A}{2L\left(\cos\gamma - \frac{\varphi_A}{2}\right)} \text{ and } \frac{\varphi_B}{2} = \frac{f_B}{2L\left(\cos\gamma + \frac{\varphi_A}{2}\right)}$$

can be neglected in comparison with the angle γ, and we have, if f_A assumed $\simeq f_B$,

$$\Delta_A + \Delta_B \simeq 2f \tan\gamma,$$

and further

$$a_A + a_B \simeq \frac{2f \tan\gamma}{a}.$$

If the change in length of A and B, by the exerted force, is not taken in consideration, on account of being so very small, we have from the former assumption and with reference to Figs. 8 and 8a,

$$\frac{1}{J_A E_A}\left[\frac{N\cos\gamma l^2}{2} - Z_B\left(La\cos\gamma\cos 2\gamma + \left(L_1 L - \frac{L^2}{2}\right)\sin 2\gamma\right)\right] + \frac{2f\tan\gamma}{a} = 0;$$

therefore, the deflection

$$f = \frac{a}{2J_A E_A \tan\gamma}\left[Z_B\left(La\cos\gamma\cos 2\gamma + \left(L_1 L - \frac{L^2}{2}\right)\sin 2\gamma\right) - \frac{N\cos\gamma l^2}{2}\right] \quad \ldots\ldots\ldots \quad (11)$$

But the deflection is also

$$f = \frac{1}{J_A E_A}\left[N\cos\gamma\left(\frac{l^2 L}{2} - \frac{l^3}{6}\right) - Z_B\left(\frac{aL^2}{2}\cos\gamma\cos 2\gamma + \frac{L_1 L^2}{2} - \frac{L^3}{6}\left(\sin 2\gamma\right)\right)\right] \quad \ldots\ldots \quad (11a)$$

Forming a new equation from (11) and (11a), both being equal, we obtain the following value of Z_B:

$$Z_B = \frac{N\cos\gamma\left(Ll^2 + \frac{l^2 a}{2\tan\gamma} - \frac{l^3}{3}\right)}{L\left(\frac{a^2\cos\gamma\cos 2\gamma}{\tan\gamma} + \left(L_1 - \frac{L}{2}\right)\frac{a\sin 2\gamma}{\tan\gamma} + La\cos\gamma\cos 2\gamma + \left(L_1 L - \frac{L^2}{3}\right)\sin 2\gamma\right)} \quad \ldots \quad (12)$$

Assuming the following values, $\cos\gamma = 0.98$, further $\tan\gamma = 0.2$; $\sin 2\gamma = 0.385$ and $\cos 2\gamma = 0.922$; then, with a numerical example, with values equal to the previous examples and with $L_1 = L + a\sin\gamma \simeq 170$ cm., from

Assuming the following values, $\cos\gamma=0.98$, further $\tan\gamma=0.2$; $\sin 2\gamma=0.385$ and $\cos 2\gamma=0.922$; then, with a numerical example, with values equal to the previous examples and with $L_1=L+a\sin\gamma\simeq 170$ cm., from equation (12) we will have:

$$Z_B=\frac{0.98\times 1400\left(160\times 100^2+\frac{50\times 100^2}{2\times 0.2}-\frac{100^3}{3}\right)}{160\left[\frac{0.98\times 0.922\times 50^2}{0.2}+\left(170-\frac{160}{2}\right)\frac{50\times 0.385}{0.2}+160\times 50\times 0.98\times 0.922+\left(170\times 160-\frac{160^2}{3}\right)0.385\right]}=630 \text{ kg.}$$

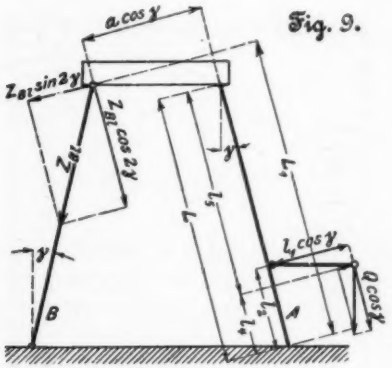
The deflection f is found from equation (11a) to be:

$$f=\frac{1}{9000\times 1000000}\left[0.98\times 1400\times\left(\frac{160\times 100^2}{2}-\frac{100^3}{6}\right)\right.$$
$$\left.-630\left(\frac{50\times 160^2}{2}\times 0.98\times 0.92+\left(\frac{170\times 160^2}{2}-\frac{160^3}{6}\right)\times 0.385\right)\right]=0.016 \text{ cm.}$$

From this example it appears that the force Z_B as well as the deflection f is reduced. The decrease of Z_B is of not much account for the frames, which are always under tension or compression, due to stress of force P, but the very small deflection, which can be increased by vibration under certain circumstances, is of great value so far as the steadiness of the engine is concerned.

The deflection due to the force Q at point C is found, from the foregoing reasoning and with assistance of Fig. 9, to be,

Fig. 9.



$$\frac{1}{J_A E_A}\left[Q\left(\cos^2\gamma\, l_1 l_2 - \sin\gamma\,\frac{l_4^2}{2}\right) - Z_{Bl}\left(La\cos\gamma\cos 2\gamma + \left(L_1 L - \frac{L^2}{2}\right)\sin 2\gamma\right)\right] + \frac{2f_l\tan\gamma}{a} = 0,$$

therefore,

$$f_l = \frac{a}{2J_A E_A\tan\gamma}\left[Z_{Bl}\left(La\cos\gamma\cos 2\gamma + \left(L_1 L - \frac{L^2}{2}\right)\sin 2\gamma\right) - Q\left(\cos^2\gamma\, l_1 l_2 - \sin\gamma\,\frac{l_4^2}{2}\right)\right], \quad . \quad . \quad . \quad . \quad (13)$$

but is also

$$f_l = \frac{1}{J_A E_A}\left[Q\left(\cos^2\gamma\left(\frac{l_1 l_2^2}{2} + l_1 l_2 l_3\right) - \sin\gamma\left(\frac{l_4^3}{2} + \frac{l_4^2 l_5}{2}\right) - Z_{Bl}\left(\frac{aL^2}{2}\cos\gamma\cos 2\gamma + \left(\frac{L_1 L^2}{2} - \frac{L^3}{6}\right)\sin 2\gamma\right)\right]; \; . \; . \; (13a)$$

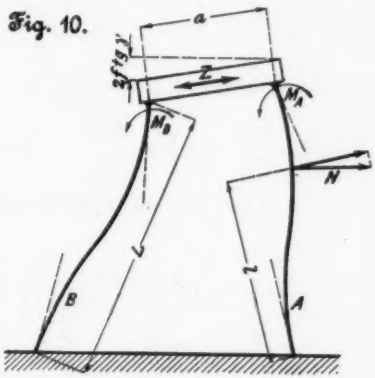
and from the combination of (13) and (13a)

$$Z_{Bl} = \frac{Q\left(\cos^2\gamma\,(l_1 l_2^2 + 2l_1 l_2 l_3) - \sin\gamma\left(\frac{2l_4^3}{3} + l_4^2 l_5\right) + \frac{a}{\tan\gamma}\left(\cos^2\gamma\, l_1 l_2 - \sin\gamma\,\frac{l_4^2}{2}\right)\right)}{L\left[\frac{a^2\cos\gamma\cos 2\gamma}{\tan\gamma} + \left(L_1 - \frac{L}{2}\right)\frac{a\sin 2\gamma}{\tan\gamma} + La\cos\gamma\cos 2\gamma + \left(L_1 L - \frac{L^2}{3}\right)\sin\right.}$$

. . . (14)

Returning now to the original assumption for column B, that it be rigidly fastened to the bed plate and at the upper end, there is found with the same suppositions which we used in obtaining the equations (11) to (14) and with assistance of Fig. 10,

Fig. 10.



$$\frac{Z\cos\gamma\frac{L^2}{2} - M_B L + \frac{2f\tan\gamma}{a}}{J_B E_B} = 0,$$

and

$$f = \frac{1}{J_B E_B}\left(M_B L - \frac{Z\cos\gamma\, L^2}{2}\right)\frac{a}{2\tan\gamma},$$

but the deflection f is also

$$f = \frac{1}{J_B E_B}\left(Z\cos\gamma\frac{L^3}{3} - \frac{M_B L^2}{2}\right);$$

from which it follows

$$M_B = \frac{Z\cos\gamma\left(\frac{2}{3}L^2 + \frac{La}{2\tan\gamma}\right)}{L + \frac{a}{\tan\gamma}}; \quad \ldots\ldots (15)$$

consequently,

$$f = \frac{1}{J_B E_B} Z\cos\gamma\left(\frac{L^3}{3} - \frac{\frac{L^4}{3} + \frac{L^3 a}{4\tan\gamma}}{L\frac{a}{\tan\gamma}}\right) \quad \ldots (16)$$

For the housing A, we now have

$$\frac{N\cos\gamma\, l^2}{2} - M_A L - Z\cos\gamma\frac{L^2}{2} + \frac{2f\tan\gamma}{a} = 0,$$

$$f = \frac{1}{J_A E_A}\left(\frac{Z\cos\gamma\, L^2}{2} + M_A L - N\cos\gamma\frac{l^2}{2}\right)\frac{a}{2\tan\gamma}; \quad . \quad (17)$$

but the 2d equation for deflection f of housing A is

$$f = \frac{1}{J_A E_A}\left(N\cos\gamma\left(\frac{Ll^2}{2} - \frac{l^3}{6}\right) - \frac{M_A L^2}{2} - Z\cos\gamma\frac{L^3}{3}\right), \quad (17a)$$

and from the combination of (17) and (17a) is found the value of M_A.

$$M_A = \frac{N\cos\gamma\left(l^2 + \frac{l^2 a}{2L\tan\gamma} - \frac{l^3}{3L}\right) - Z\cos\gamma\left(\frac{2}{3}L^2 + \frac{La}{2\tan\gamma}\right)}{L + \frac{a}{\tan\gamma}}. \quad (18)$$

This value of M_A placed in equation (17a) gives for f

$$f = \frac{1}{J_A E_A}\left[N\cos\gamma\left(\frac{Ll^2}{2} - \frac{l^3}{6} - \frac{\frac{L^2 l^2}{2} + \frac{Lal^2}{4\tan\gamma} - \frac{Ll^3}{6}}{L + \frac{a}{\tan\gamma}}\right) - Z\cos\gamma\left(\frac{L^3}{3} - \frac{\frac{L^4}{3} + \frac{L^3 a}{4\tan\gamma}}{L + \frac{a}{\tan\gamma}}\right)\right], \quad (19)$$

and from this result finally, by combination of equations (16) and (19), we derive Z.

$$Z = \frac{N\left(Ll^2 - \frac{l^3}{6} - \frac{\frac{L^2 l^2}{2} + \frac{Lal^2}{4\tan\gamma} - \frac{Ll^3}{6}}{L + \frac{a}{\tan\gamma}}\right) J_B E_B}{\left(\frac{L^3}{3} - \frac{\frac{L^4}{3} + \frac{L^3 a}{4\tan\gamma}}{L + \frac{a}{\tan\gamma}}\right)(J_A E_A + J_B E_B)}. \quad . \quad (20)$$

For better explanation of the foregoing we will take an example in which the same numerical values are used as in the earlier cases.

Again, $E_A = E_B = 1000000$, $J_A = 9000$ cm.^{4}, $J_B = 7000$ cm.^{4} The force Z is found to be from equation (20),

$$Z = \frac{1400\left(\frac{160\times100^2}{2} - \frac{100^3}{6} - \frac{\frac{160^2\times100^2}{2} + \frac{160\times50\times100^2}{4\times0.2} - \frac{160\times100^3}{6}}{160+\frac{50}{0.2}}\right)7000}{\left(\frac{160^3}{3} - \frac{\frac{160^4}{3} + \frac{160^3\times50}{4\times0.2}}{160+\frac{50}{0.2}}\right)\times(9000+7000)} = 417 \text{ kg.}$$

From equation (15)

$$M_B = 417\times0.98\left(\frac{\frac{2}{3}\times160^2 + \frac{160\times50}{2\times0.2}}{160+\frac{50}{0.2}}\right) = 37000 \text{ cm. kg.}$$

and from equation (18)

$$M_A = \frac{1400\times0.98\left(100^2 + \frac{100^2\times50}{2\times160\times0.2} - \frac{100^3}{3\times160}\right) - 417\times0.98\left(\frac{2}{3}\times160^2 + \frac{160\times50}{2\times0.2}\right)}{160+\frac{50}{0.2}} = 15800 \text{ cm. kg.}$$

The deflection f from equation (16) is

$$f = \frac{417 \times 0.98}{7000 \times 1000000}\left(\frac{160^3}{3} - \frac{\frac{160^4}{3} + \frac{160^3 \times 50}{4 \times 0.2}}{160 + \frac{50}{0.2}}\right) = 0.0122 \text{ cm.}$$

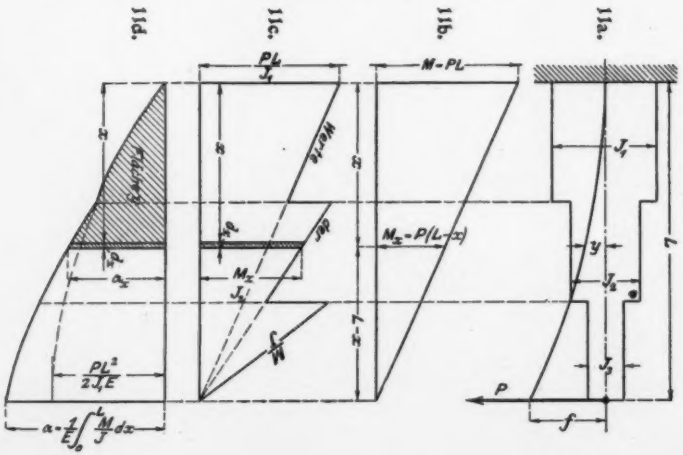
From these results it appears that the deflection decreases if the frames have an inclined position. Comparing the amount of deflection, f, of the last example with the deflection, f, of the former example, obtained with equation (3), it is found that the latter deflection is only $\frac{0.0122}{0.0205} = 0.6$ of the former.

Stationary steam engines of the vertical, inverted type are generally designed as shown in Fig. 1, with columns either cast iron or wrought iron or steel in front, while the back frames are housings, cast with the crosshead guide face in one piece.

The columns are generally round and of the same diameter, or nearly so, over their whole length; therefore the moments of inertia of all sections are equal or very nearly equal, but the sections of the housing and their corresponding moments are different over their entire length; likewise is the line through the centers of gravity of the sections not a straight line.

To arrive at the angles of deviation and the deflection, and

Fig. 11a to 11d.



from these to approximate the distribution of stress, there may be used with advantage the following graphic method, first introduced by Mr. Mohr.

On a beam of length L, rigidly fastened at one end and loaded at the other end with the load P, the bending moment at a distance x from the support is, as well known,

$$Mx = P(L - x).$$

If this moment is divided by the moment of inertia J_2 of section x, it gives

$$\frac{Mx}{J_2} = \frac{P}{J_2}(L - x).$$

This manipulation repeated for different sections of the length and the values of the $\frac{M}{J}$ placed as ordinates upon an axis, will give, as boundary, a new line (see Fig. 11c), which will be a straight line (see Fig. 11b) only if the moments of inertia are equal for all sections. This line is rising from 0 at the end.

From the equation of the elastic line

$$M = \frac{d^2y}{dx^2} JE$$

is obtained, by single integration, the angle of deviation of the elastic line from the original straight axis of the beam, at a distance x, to be

$$\alpha x = \frac{dy}{dx} = \frac{1}{E}\int_0^x \frac{M}{J}\,dx.$$

If the value

$$\frac{1}{E}\int_0^x \frac{M}{J}\,dx$$

for every x, is placed as ordinate, to a suitable scale upon an axis, it gives as boundary a new curved line (see Fig. 11d), which encloses with the axis the area y,

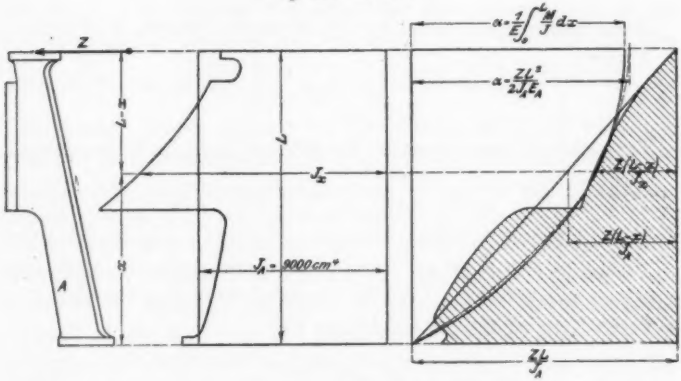
$$y = \frac{1}{E}\int_0^x \alpha\,dx,$$

and y is a measure for the deflection f of the beam at a distance x.

If, simultaneously, the values of unchangeable moments of in-

ertia of a column are placed on the corresponding ordinates we can, by comparison, find the absolute deflection of the housing by the difference of these ordinates of the respective areas. It is sufficient, however, to calculate with a mean moment of inertia without making any great error, as is shown in Fig. 12b with a housing of such shape as sketched in Fig. 12a.

Fig. 12a to 12c.



The difference of area with this simplification, as shown in Fig. 12c, is less, or about 2 per cent. This approximation is sufficiently correct as compared with the assumption used in the calculation, which is also, in reality, only partly fulfilled.

If the construction of the frames allows an increase of the distance between the upper ends of the column and housing in warming the cylinders, it produces an additional strain in the frames, but this can be avoided, and this strain will therefore not here be taken into consideration.

All single moments are now known from the foregoing equations, and with these moments can be found all bending stresses, which, in connection with the tensile or compressive stress of the piston force, form the total stress on the frames; but it is also of great importance to find the stress on the connection bolts at the cylinder and bedplate end of the frames respectively.

In addition to the stress from the piston force, the bending moments produce stress on the bolts, and this latter stress can, under certain circumstances, be greater than the former.

U. S. Submarine Torpedo Boat "Adder" at the Speed of 8.86 Knots on the Surface. Note the Peculiar Bow Wave and the Hollow Just Abaft it and Abreast the Mast.

OFFICIAL TRIALS OF SUBMARINE BOATS *ADDER* AND *MOCCASIN.*

By William Russell White, Lieutenant, U. S. Navy.

Submarine navigation, though successfully attempted in shallow water by Robert Fulton nearly a century ago, is yet to be actually accomplished for any continuous period in deep water, though the possibility and the practicability of such work is strongly maintained.

Some success has been secured by the French Admiralty in this direction, but when results are critically analyzed it is found that further experimentation and much improvement are essential in special directions.

The United States Navy has had one submarine boat (*Holland*) in commission for over three years. Although the craft has had a very capable, daring and energetic commander, there is no official record that she has ever done submerged work off the entrance of any of the principal harbors, except for the briefest interval. This type of boat is designed to operate in such localities—not in land-locked and shallow harbors.

In June, 1900, the Congress authorized the construction of six additional submarine boats of an improved *Holland* type. Two of these boats, the *Adder* and *Moccasin*, were officially tested in the sheltered and shallow waters of Peconic Bay, Long Island, in November last. These tests continued for a period of seven days, and it is to be regretted that the official trials did not take place in deeper water, so that the endurance, the habitability and the stability of the boats while in unprotected waters could have been more definitely ascertained.

The trials were witnessed in their entirety by the Naval Board of Inspection and Survey. The writer of this article was particularly detailed to observe and report upon the performance of the

boat at the special request of the Engineer-in-Chief of the Navy, and he was present in both boats during every trial.

Three artillery officers from the School of Submarine Defense witnessed, from the tenders of the submarine boats, the 3-hour submerged run of the *Adder;* also the mile submerged run of the *Moccasin* when that boat fired her torpedo.

The limited capacity of the submarines and the character of their construction made it impossible for other than two or three of the naval officers, the crew of the boats, consisting of six men, and a representative of the Holland Company to enter the craft during the submerged tests. Those who actually entered the boats thus had opportunity for securing reliable information that was not within the reach of any one who simply witnessed the performances of the submarines from tenders or from tugs.

BRIEF DESCRIPTION.

The *Adder* and *Moccasin* are sister boats, being improved *Hollands*. Their hulls are cigar-shaped, like that of a Whitehead torpedo, every cross section being a circle; the greatest diameter is 11 feet 10 inches, and the length 63 feet 4 inches.

For propulsion on the surface power is transmitted to the propeller shaft, through means of gearing, by two methods—

(1.) By a 4-cylinder gasoline engine of 160 horsepower, each cylinder of which can be used independently of the others.

(2.) By a 70-horsepower electric motor which receives current from storage batteries having a capacity of 1,900 ampère-hours at the normal rate of discharge.

When leaving or coming alongside a dock or vessel the electric motor alone is used, because there is no way to reverse the screw when using the gasoline engine.

Only the electric motor can be used for submarine propulsion, because it is then impossible to secure sufficient air to operate the gasoline engine, and it is also impossible to get rid of the dangerous gases of combustion that leak from joints and from valves into the boat.

Submergence is obtained by the use of diving rudders and the filling of the trimming and the ballast tanks. The proper trim

for submergence is obtained by admission of water to the forward and to the after trimming tanks and to the main ballast tank. When the proper quantity of water has been admitted to the necessary tanks the boat is very sensitive to the action of the diving rudder, but a speed of at least six knots is required to control the vertical movement of the craft.

Emergence is obtained by the expulsion of the water ballast and by operating the diving rudders. The expulsion of the water from the ballast tanks is secured by the direct use of air from the storage flasks, the required pressure being maintained by reducing valves.

The diving and the vertical rudders are worked by hand, the power being transmitted very satisfactorily through gearing. The complicated and delicate air engines for operating the horizontal and the vertical rudders, as installed on the *Holland*, having been removed. Experience has shown that more reliable and satisfactory results are secured by relying on the skill and on the intelligence of the crew and not upon the certainty of action of presumably automatic devices, which are liable to fail at critical times.

PROPELLER.

A single, left-handed, three-bladed screw is used to propel these submarines. Its efficiency is very low, due to its small size, to its high pitch and to the speed of the engine. Probably these cannot be avoided except by increasing the weight of machinery, which may be inadvisable. The special points of the propeller, as will be seen in the accompanying drawing, are:

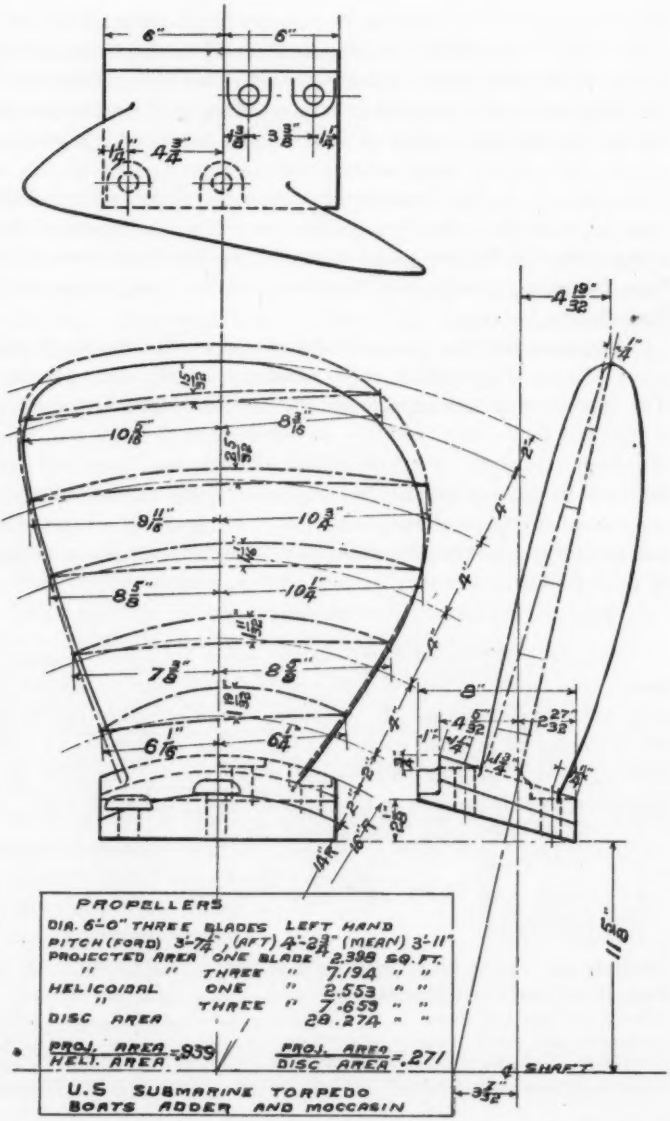
(1.) Small pitch ratio, it being but .653.

(2.) Wide blade.

(3.) Large boss, due to position on the craft.

The principal dimensions are:

Diameter, feet	6
Diameter of boss, feet and inches	2- 8
Mean pitch, feet and inches	3-11
Helicoidal area (three blades), square feet	7.659
Projected area (three blades), square feet	7.194
Disc area (three blades), square feet	28.274


6"
6"
4 19/32"
1/4"
2"
4"
4"
4"
4"
2"
8"
4 5/32"
2 27/32"
1/4"
1 13/32"
1/4"
2 5/32"
1 1/2"
2"
2"
2"
14"
6"
1"
2"
PROPELLERS
DIA. 6'-0" THREE BLADES LEFT HAND
PITCH (FORD) 3'-7 1/4", (AFT) 4'-2 3/4" (MEAN) 3'-11"
PROJECTED AREA ONE BLADE 2.398 SQ. FT.
" " THREE " 7.194 " "
HELICOIDAL ONE " 2.553 " "
" THREE " 7.659 " "
DISC AREA 28.274 " "
PROJ. AREA / HELI. AREA = .939
PROJ. AREA / DISC AREA = .271
U.S SUBMARINE TORPEDO BOATS ADDER AND MOCCASIN
11" DIAG
4 SHAFT
3 7/32"

WEATHER DURING TRIALS.

In general the weather was good, but at all times it was chilly and there were several days when it was quite cold. With the exception of one day, the water in Peconic Bay was perfectly smooth whenever a trial was held. Fickle tidal currents made standardization speeds rather uncertain.

SCOPE OF TRIALS.

In addition to the observers within the submarines who took data, the standardization runs were witnessed from tenders by other observers, who took full notes of all that transpired. These tenders ran parallel with the submarines, a straight course having been marked out by flags. Particular care was taken that the tenders should in no way annoy nor interfere with the official trials of the boats under test. The endurance runs were likewise observed and reported upon by officers stationed on boats following in wake of the submarine.

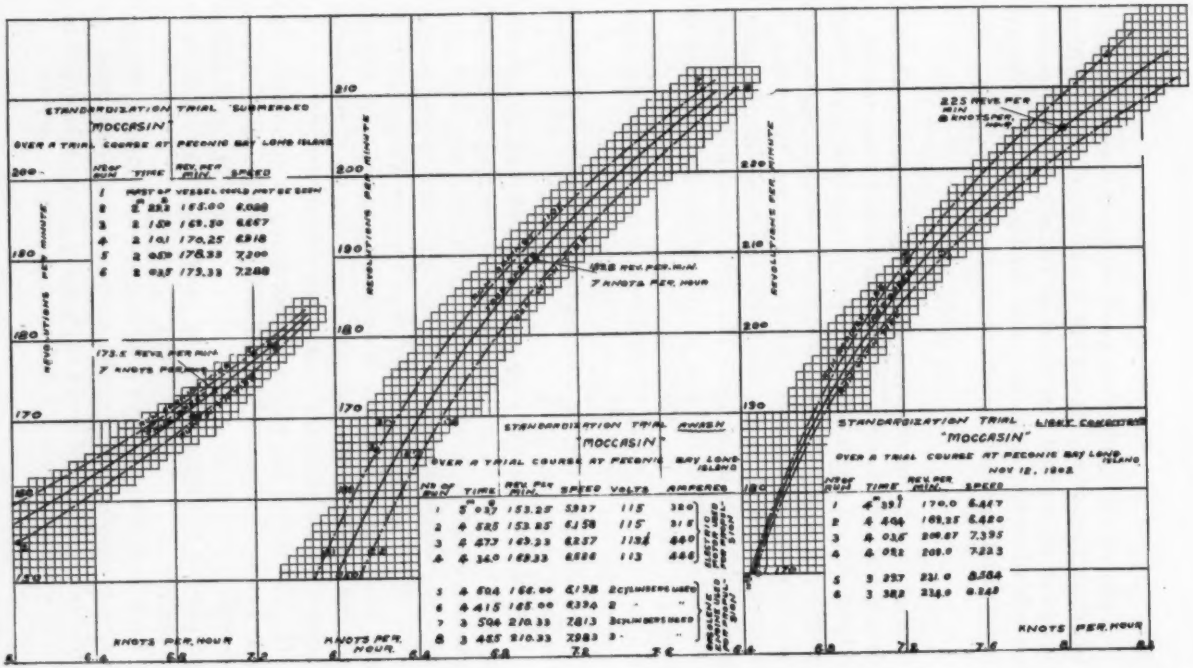
The *Adder* and the *Moccasin* were standardized on the measured course in three conditions of draft:

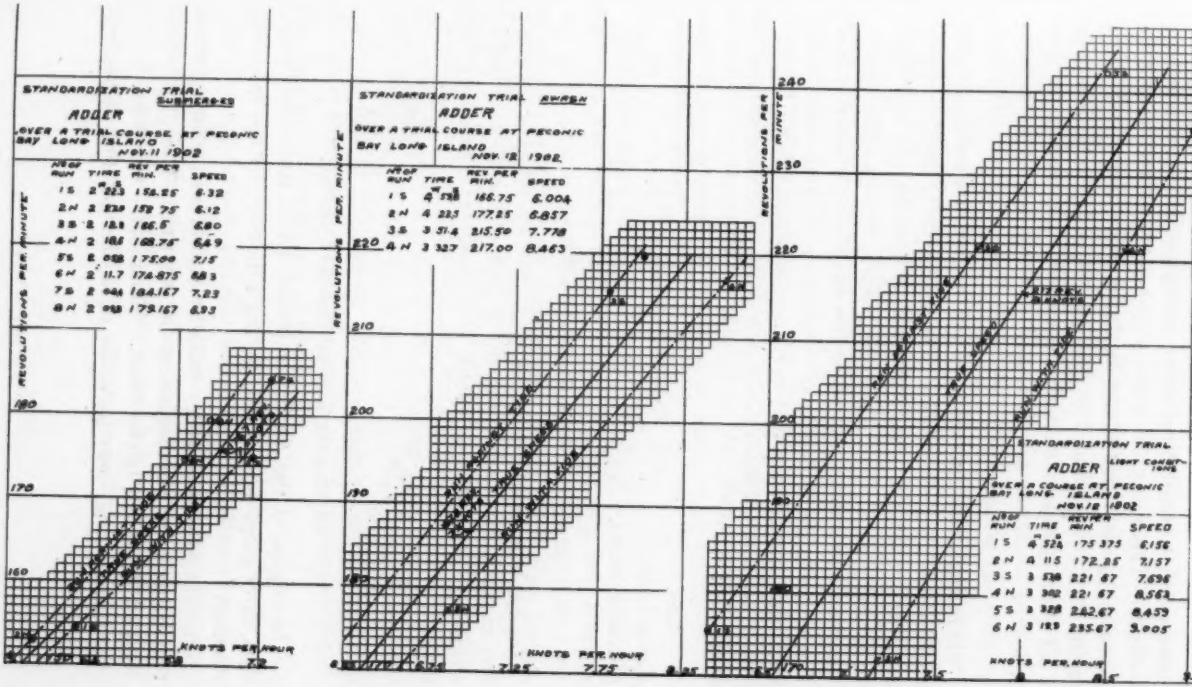
(1.) *Light*, the ordinary cruising condition, propelled only by the gasoline engine.

(2.) *Awash*, improperly so called, propelled by the gasoline engines, trimmed for diving, except that the main ballast tank was empty and the conning-tower hatch cover was kept open, but with everything else in readiness for commencing submerged work. When cruising in this manner the boat is supposed to be able to dive at short notice, it only being necessary to stop the gasoline engine, fill the main ballast tank, start the electric motor, secure a 6-knot speed and operate the rudder.

(3.) *Submerged*, the electric motor being in operation. The boat having been put in trim for diving, she is then given a reserve buoyancy of about 300 pounds in order to provide against the possible contingency that the diving gear may fail to work properly.

Each boat, when in *light* condition, had a 10-knot endurance run, thus showing the speed which could be secured from the gasoline engine. One of the boats had a 3-hour submerged en-


STANDARDIZATION TRIAL SUBMERGED
"MOCCASIN"
OVER A TRIAL COURSE AT PECONIC BAY LONG ISLAND
HOUR RUN TIME REV. PER MIN. SPEED
1 MAST OF VESSEL COULD NOT BE SEEN
2 2 22.3 165.00 8.088
3 2 15.8 169.50 8.667
4 2 10.1 170.25 8.916
5 2 05.9 178.33 7.200
6 2 03.5 179.33 7.288
175.5 REVS. PER MIN.
7 KNOTS PER HOUR
REVOLUTIONS PER MINUTE
KNOTS PER HOUR
STANDARDIZATION TRIAL AWASH
"MOCCASIN"
OVER A TRIAL COURSE AT PECONIC BAY LONG ISLAND
END OF RUN TIME REV. PER MIN. SPEED VOLTS AMPERES
1 5 03.7 153.25 5.937 115 320
2 4 58.5 153.85 6.158 115 315
3 4 47.3 169.33 6.857 113.4 440
4 4 34.0 169.33 6.886 113 446
5 4 50.4 168.00 6.138 2 CYLINDERS USED
6 4 41.5 165.00 6.396 2 " "
7 3 59.6 210.33 7.813 3 CYLINDERS USED
8 3 48.5 210.33 7.983 3 " "
ELECTRIC POWER USED FOR LIGHTING AND AUXILIARIES
225 REVS PER MIN @ KNOTS PER HOUR
STANDARDIZATION TRIAL LIGHT CONDITION
"MOCCASIN"
OVER A TRIAL COURSE AT PECONIC BAY LONG ISLAND
NOV 12, 1908
HOUR RUN TIME REV. PER MIN. SPEED
1 4 39.1 170.0 6.467
2 4 40.4 169.25 6.420
3 4 03.6 209.67 7.395
4 4 01.2 209.0 7.323
5 3 25.7 231.0 8.584
6 3 38.2 234.0 8.268


STANDARDIZATION TRIAL
SUPPRESSED
ADDER
OVER A TRIAL COURSE AT PECONIC BAY LONG ISLAND
NOV. 11 1902
REVOLUTIONS PER MINUTE
KNOTS PER HOUR
STANDARDIZATION TRIAL
SMASH
ADDER
OVER A TRIAL COURSE AT PECONIC BAY LONG ISLAND
NOV. 12 1902
REVOLUTIONS PER MINUTE
KNOTS PER HOUR
STANDARDIZATION TRIAL
ADDER
OVER A COURSE AT PECONIC BAY LONG ISLAND
NOV 13 1902
LIGHT CONDITION
REVOLUTIONS PER MINUTE
KNOTS PER HOUR

durance test to find the actual working capacity of the storage batteries. There was also made a 12-hour endurance test of the gasoline engine of one of the boats, in order to find out if the engine could be operated for that period, and also to determine if all four cylinders could be operated continuously for that period.

STANDARDIZATION RUNS.

There were two courses over which the standardization runs were made. For the surface runs, where the gasoline engines alone were used, the standardization course was one-half knot; for the submerged runs, where the electric motors alone were in operation, the standardization course was only one-quarter knot. The points for the standardization speed curves were thus secured from runs over courses that were comparatively short. The corrected maximum speeds developed during the various runs are as follows:

Boat.	Light.	Awash.	Submerged.
Adder, knots, ...	8.732	8.12	7.08
Moccasin, knots, ...	8.416	7.898	7.244

SURFACE ENDURANCE RUNS.

Both submarines were run under all four cylinders of the gasoline engines, the *Adder's* run being part of the 12-hour endurance run. The following speeds were made for a distance of ten knots:

Adder, knots, ...	8.86
Moccasin, ...	8.5

ENDURANCE RUN OF GASOLINE ENGINE.

The engine of the *Adder* ran twelve hours under four cylinders, three stops being made during this time, for the following reasons:

(1.) The igniter of No. 1 cylinder commenced blowing about two hours after the beginning of the run. The engine was stopped and a new igniter fitted. Time lost, 8 minutes.

(2.) In getting away from the dock the gasoline engine was

discontinued and the electric motor put in use. Time lost, 6 minutes 40 seconds.

(3.) For coming alongside the dock the gasoline engines were again stopped to permit the use of the electric motor and to secure to the dock. Time lost, 17 minutes 40 seconds.

There were thus three stoppages of the gasoline engine, and during these periods the cylinders were necessarily permitted to cool off. The 24 minutes that were lost in leaving the dock and then in securing alongside were made up by running the gasoline engine that additional time.

At the end of the surface run there were no offensive odors perceptible from the use of the gasoline. It should be remembered, however, that CO, one of the products of combustion is odorless and very poisonous, and that another, CO_2, is heavier than air, inert, odorless and incapable of supporting life. It is thus possible that there may have been debilitating gases which could not be detected by the sense of smell.

SUBMERGED ENDURANE RUN.

The *Adder* ran in a submerged condition, with the electric motors in use, for a period of 3 hours. During the first 2 hours and 20 minutes of this trial her motor made sufficient revolutions to give the boat an average speed of 7 knots. The time lost in firing the torpedo was made good. During the last half of the third hour the speed of the boat decreased, due to the fact that the storage battery ran down, the voltage having fallen rapidly. The average speed for the 3 hours during the submerged run was 6.88 knots, 7 knots being required by the contract.

At the end of this run no offensive odors were perceptible. The air in the boat, however, was stuffy, and the observers noted that they had some feeling of discomfort.

CONNING.

During the surface and the awash runs the submarines were conned as any ordinary steamboat. While making the submerged run the conning was done entirely by compass. Light is admitted to the conning tower through lenses, but the effect on looking out is like that of a thick, green haze. It is abso-

lutely essential that the submarine should frequently come to the surface to get her bearings, unless the locality is very well known to the helmsman. It would be possible where the channel is straight and deep for the helmsman to follow the prescribed course, but he should never forget that the tide is always acting at its full strength on his boat.

So far as could be seen from the observer's boat, the submarine ran nearly a straight course, turned and returned as well as if she had been steered by ranges at the surface. The position of the submarine during the run was indicated by a small flag carried at the head of a mast temporarily attached to the boat.

PERISCOPE.

During the 3-hour submerged run of the *Adder* the conning was done entirely by means of a periscope temporarily rigged through the port forward ventilator. This instrument was fixed in position and had a field in view of but 15 degrees on each bow. For over two hours the *Adder* remained submerged without coming to the surface to take an observation, and during this time her average depth as shown on the gauge was about 11 feet, making the conning tower about 7½ feet below the surface.

It is absolutely essential to the efficiency of this type of boat that a properly-designed periscope be built and then supplied for conning. A submarine can then remain below the surface for a couple of hours without constantly coming up for observations, thereby necessarily exposing itself to the enemy's fire. When there is the slightest disturbance of the water, vision through the lenses of the conning tower is very difficult on account of the spray and water thrown on them. With a proper periscope the height of the objective lense above water can be so regulated that there will be little or no annoyance from this cause.

When using a periscope, the relative position of objects is, of course, quite apparent, but it is absolutely impossible to judge distances with any degree of accuracy. Cases have been known where submarines have rammed a sea wall which, seen through the periscope, appeared to be quite distant.

THE ADDER TOUCHED BOTTOM.

At one time during the 3-hour submerged run of the *Adder* the boat touched the sandy bottom in a depth of about 29 feet and would not answer the diving rudder. Ordinarily, when submerged and under way, this rudder is maintained at an angle of 9 degrees. On touching bottom it was shifted to 18 degrees in the opposite direction without effect.

In order to change the trim of the boat and put her down by the stern, two men were sent aft, still without affecting the release of the boat. Then the motor was slowed slightly and the main ballast tank was blown out. The force of the expulsion of the water, with the additional buoyancy thereby gained, freed the boat and the *Adder* rose to the surface.

The ballast tank was then filled and the boat answered her diving rudder, the conning tower having been exposed on the surface 1 minute and 30 seconds. The electric motor was not stopped during this mishap, because the revolutions were dropping below the number required to make the contract speed of 7 knots for three hours, and the endeavor was to maintain the maximum speed possible.

It is believed that it was only the bow which touched bottom, as the propeller was clear and the boat kept forging ahead. The bottom first touched was probably the top of a shoal, whose downward slope was followed into deeper water, as shown by the progressive increase in the readings of the depth-recording gauge.

The result might have been quite serious for the submarine if the bottom had been of a clay formation. The kinetic energy of such a large mass at seven knots speed, might, under proper conditions, be such as to partially embed a boat so that the suction would make it a very difficult matter to free her. There would then be, of course, the weight of the column of water as well as the atmospheric pressure tending to hold the submarine to the bottom, against which combination the reserve buoyancy and that gained by expelling water from the ballast and the trimming tanks might be of little avail.

It would be advisable to place a submarine boat under a pair

of shears in order to conduct a series of experiments to note whether serious danger would actually menace a submarine boat that had sunk a few inches in a soft or in a clayey bottom.

The following day the *Adder* ran aground in a dense fog, but was floated at the next high water, no harm being done her heavy, strong hull.

CONDITION OF MACHINERY.

The condition of the machinery is good. There was an occasional necessity for the renewal of igniters of the gasoline engine. When an igniter starts blowing it is absolutely necessary to disconnect its cylinder in order to prevent the escape of poisonous gases into the boat. If it is wished to use this disabled cylinder a new igniter must be fitted, and to do this it is essential that the engine be stopped unless the services of three men are immediately available, because of the very crowded and limited space for work, and on account of the excessive pressure that must be overcome during the compression period of the stroke.

Some device similar to the breech-closing mechanism of a rapid-fire gun should be installed for the special purpose of fitting igniters quickly, since there is always a probability that the gasket of the igniter will fail to remain tight.

There were no leakages of gasoline perceptible anywhere except in the neighborhood of the engine, and these odors disappeared very quickly. By reason of the weight of the gases they may have settled to the bottom of the boat. It is possible that the sensibility of smell was dulled, and at least two of the noxious gases are odorless.

Once when stopping the engine there was a back-flash due to the failure of an explosion in one cylinder. However, in the next cycle a double explosion occurred, thus forcing some of the products of combustion into the crank pits and from there into the engine room.

At least two or more of the four cylinders of the gasoline engine must be used in order to maintain sufficient speed for maneuvering purposes. It was found, when starting with one

cylinder, that speed could be kept up for only a few minutes at a time. Then the cylinder becomes warm, because there is not sufficient circulating water to prevent the walls from heating. Excessive friction probably ensues, revolutions diminish, there is less and less cooling water circulated and the engine must stop. The endurance of a single cylinder for propulsive purposes will probably not exceed 30 minutes.

TEMPERATURE.

The boat takes up the temperature of the surrounding water, which is maintained, except as slightly affected by the small amount of heat given off by human bodies and by radiation from the cylinders. During the official tests last November the weather was cold and the water was comparatively chilly, and therefore existence on the submarine was far from comfortable. The heating of these boats can be effected by electric heaters, but these appliances consume so much electric current that they were only used once, and that during the 12-hour endurance trial of the *Adder's* gasoline engine. It is hardly probable that these heaters would ever be used, except in cases of extreme emergency, because they consume so much electric current that the radius of action of these craft would be considerably reduced.

VENTILATION.

When the gasoline engine is in use such a large amount of air is required to complete the combustion of gasoline in the cylinder that the boat is apparently well ventilated. The following special appliances are installed for securing necessary ventilation:

(1.) An electric fan motor is fitted above the gasoline engine and exhausts through the after ventilator. This fan is expected to carry off the dangerous gases above the engines resulting from the various leakages, the total prevention of which is impossible.

(2.) A fan motor exhausts the air from the extreme after part of the craft towards the gasoline engine, from where it is again exhausted into the after ventilator or sucked through the crank pits into the cylinders of the engine.

(3.) The storage-battery tanks are ventilated by means of an exhaust blower which draws air from the battery cells and discharges it overboard. During the submerged runs this motor exhausts directly into the boat. There is considerable difference of opinion as to whether or not the storage battery gases are of an explosive nature.

In considering the question of ventilating submarine boats, the fact should be kept in mind that gasoline fumes are much heavier than air, and it is no easy thing for any fan motor to exhaust any heavy gas when it is surrounded by atmospheric air. It is possible for a fan to be in operation for hours without drawing any heavy gas if a lighter gas is within reach of its suction.

TORPEDO FIRING.

While the *Adder* was submerged and under way two torpedoes were fired at the target, the helmsman as nearly as possible, under the conditions, heading the boat towards the target. Similarly one torpedo was fired from the *Moccasin*. Neither boat made a hit. The torpedo that was used was of Mark I type. This torpedo was neither fitted with the Obry gear nor the gyroscope, which fact should be considered. The torpedo, however, was of a type which was furnished by the Bureau of Ordnance, Navy Department, and was therefore presumed to be reliable.

TIME REQUIRED FOR PREPARING TO DIVE.

On November 14th, the boat being in the *light* condition, it took 26 minutes to get the *Adder* ready for diving. This period of time was thus required to stop the gasoline engine, to unship ventilators, to clear and secure the conning-tower hatch, to fill the trimming and ballast tanks and to connect the electric motor to the propeller shaft.

On November 17th, again being in the *light* condition, it took the *Adder* 29 minutes and 40 seconds to make preparations for diving.

On November 18th the *Moccasin*, when in *light* condition, required 25 minutes to get in condition for diving. On this occasion a torpedo was fired.

If proper gauges had been fitted to show the correct trim of the boat both forward and aft, instead of relying entirely upon the skill and the quickness of judgment of one man, it is exceedingly probable that much less time would have been required in getting ready to dive.

Another advantage resulting from the installation of pressure gauges would rest in the fact that the ability to submerge a submarine could be more readily acquired by several of the boat's crew, and therefore the success of this evolution would not be dependent upon the experience and skill of any one man. Every operation in connection with the working of a submarine should be made as simple as possible, and no one should be permitted to form part of the crew who could not do the duty of at least one other man. Then, again, the crew should not be considered competent for the task of operating the boat unless it were possible to replace at an instant's notice any man doing any duty.

Special ventilators designed for rapid unshipping or fitted with automatic closing valves might have shortened this long period required for diving. Some attention might profitably have been given to the cleanliness of the conning-tower cover and the ventilator gaskets in order to shorten the interval for closing these openings in the boat.

No time data was recorded as to the time necessary to get ready to dive from the *awash* condition while using either a gasoline engine or the electric motor, nor was this attempted at any time. To form a correct estimate of the value of submarines, it is necessary to have exact data on this point.

STORAGE BATTERIES.

The storage batteries consist of 60 cells. They are open at the top, and in case of any sudden change of trim in a submarine, as might easily happen, it would be extremely probable that the electrolyte, sulphuric acid, would be spilled into the bilges of the vessel. It is, therefore, necessary that watertight covers should be fitted over the storage-battery tanks.

PERSONNEL.

The trial crew of the *Adder* and the *Moccasin* was thoroughly competent, well trained and highly disciplined. Particularly was this discipline manifested by the behavior of the crew when the *Adder* "sucked bottom." Although the trial actually occupied only portions of seven days, each averaging about six working hours, the crew was very much worn out at the conclusion of the tests; and yet these men did not sleep aboard, and even their meals were obtained on shore.

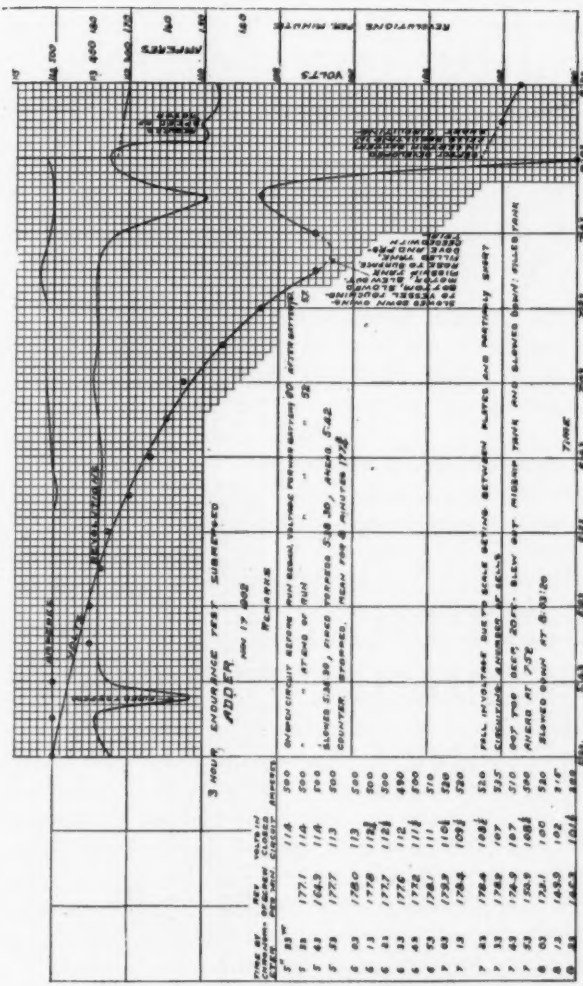
Owing to the positions of the wheels, the two helmsmen who operate the horizontal and the vertical rudders, have uncomfortable positions while in the performance of their work. Besides the physical fatigue resulting from continuous work and from constrained positions, these men are likewise subject to a mental strain which is very evident, and which induces exhaustion quite rapidly.

STABILITY.

The boats having been put in trim for diving, two men weighing 370 pounds moved to the extreme end of the bow of the submarine, whereupon the boat inclined by the head 2 degrees. When these men moved aft as far as they could get the trim was altered to $1\frac{1}{2}$ degrees down by the stern. When submerged and under way it is essential that the members of the crew remain in the near vicinity of their respective stations. They are not required to remain absolutely quiet in one position, as a small amount of movement is permissible.

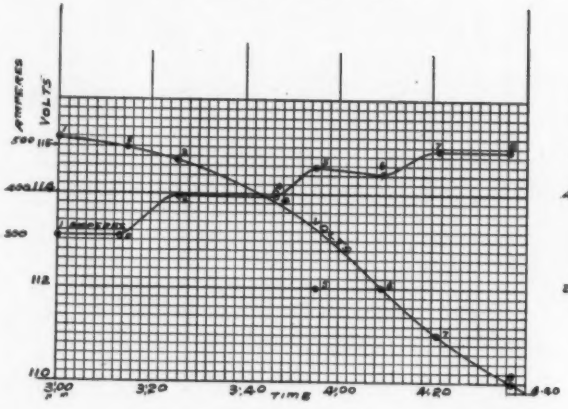
ENDURANCE.

In smooth water, where the top of the conning tower can be kept open, the gasoline engine is used to propel the submarines. Under such conditions enough air is supplied for the use of the cylinders and for ventilation, even should the top of the conning tower be partly closed. It is believed that in a seaway it will be absolutely necessary to close the top of the conning tower. In such a case the electric motor would have to be used, because the only way of supplying the large quantity of air requisite for the operation of the gasoline engines is through the hatch in



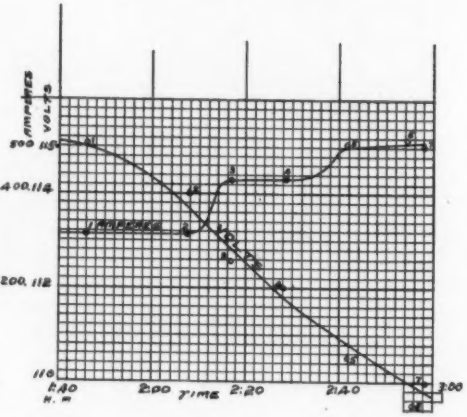
CURRENT USED ON SUBMERGED TRIAL
ADDER
OVER A TRIAL COURSE AT PECONIC BAY LONG ISLAND
NOV 11 1902

No of RUN	TIME	VOLTS	AMPERES
1	3″ 00	115.17	311
2	3 13.5	115.0	310
3	3 25.8	114.7	397
4	3 46.1	114.0	395
5	3 54.9	112.0	457
6	4 09.7	112.0	447
7	4 21.4	111.0	495
8	4 36.8	110.0	497



CURRENT USED ON SUBMERGED TRIAL
"MOCCASIN"
OVER A TRIAL COURSE AT PECONIC BAY LONG ISLAND
NOV. 15 1902

No of RUN	TIME	VOLTS	AMPERES
1	1″ 46″	115	310
2	2 08	114	310
3	2 17	112½	425
4	2 29	112	425
5	2 42	110½	500
6	2 56	105½	510
7	2 59	110	500



the top of the conning tower. If it were possible to use the gasoline engine when this hatch is closed, noxious gases would, in all probability, leak into the boat during its use, and under the conditions they would be hard to expel.

The endurance of the storage batteries was but four hours during the tests preliminary to installation. During the submerged endurance run the battery had an endurance of but three hours, the craft making a speed of 6.88 knots. The radius of action is probably 21 knots for submerged work at the maximum speed. This is the condition under which the boat was specially designed to operate, the special function of the submarine being submerged work.

It was found when the customary reserve buoyancy was given and the boats put in proper trim for diving that with a less speed than 6 knots the diving rudder could not control the depth of immersion with certainty, and therefore the maneuvering qualities of the craft were greatly impaired.

When in a submerged condition the radius of action, therefore, will be the distance for which the battery will be effective when the boat is running at a speed not less than 6 knots. The endurance in this respect and at this speed was not tested, but this radius of action will certainly not be much more than 30 knots.

From what the writer observed as to the performance of the *Adder* and the *Moccasin*—and he was on board both boats during every submerged and every surface run that they made on these official tests—he is convinced that the limitations of the submarines for continuous submerged work is proportionate to the capacity of the storage battery, to the skill and to the physical endurance of the crew.

It has been reported that a boat of this type has spent fifteen hours under water, with five men, and that they suffered no discomfort from the test. It should be noted that the boat was not then under way, and therefore neither exertion nor strain nor much responsibility devolved upon any one in the boat. It was simply requisite that these men had sufficient knowledge of the various appliances to effect emergence at will. This experiment

merely showed the air capacity of the craft. The problem as to how much air a man needs is a matter of record, and if there is no leakage of gasoline from the tanks or from the engine, it should be an easy matter to determine how long any number of men could remain in any boat of a particular size.

The boats were neither fitted with tanks for holding a supply of potable water nor were there any ordinary facilities for cooking, though an electric heater was installed. By reason of the excessive amount of current consumed in its operation this appliance could be only used intermittently. The radius of action of the boat would be greatly lessened in cold weather if the heater was used continuously either for cooking or for making the living spaces approach a comfortable temperature.

USEFULNESS.

Any blockading fleet operating against the coast of a country which possesses submarines would find it necessary to take extra precautions to ward off attacks of the submarine craft. The boat therefore possesses much defensive value if for no other reason than the moral effect which would be produced by its use.

The extravagant claims as to the sea-going qualities and to the large radius of action of the craft were not proved on these official tests. There is no doubt, however, but that the submarine must hereafter be taken into account as a practical and useful element of seacoast defense.

Their dirigibility in shallow water, their habitability for short intervals in a submerged condition, and their limited radius of action have been demonstrated. They should now be subjected to the test of some sustained sea work.

For the last line of defense, and as an auxilliary to fortifications, the submarine, when properly developed and when well handled, may become a valuable military weapon. Its habitability, its maneuvering powers and its stability are yet to be satisfactorily shown when the boat is exposed to wind and waves such as are encountered off the approaches to any harbor of commercial importance or strategic value.

ACTUAL PERFORMANCE OF BABCOCK AND WILCOX BOILERS AS INSTALLED IN U. S. S. *MARIETTA*, WITH GENERAL OBSERVATIONS ON PRACTICAL REQUIREMENTS AND THE SUCCESSFUL OPERATION OF MARINE WATER-TUBE BOILERS.

By Henry C. Dinger, Ensign, U. S. N., Senior Engineer, U. S. S. "Marietta."

The two Babcock and Wilcox boilers of the *Marietta* are now nearly six years old. The vessel was put in commission in September, 1897, and has had active service ever since. During this period she made the voyage from the Pacific Coast to Santiago, Cuba, to join the naval force of Admiral Sampson.

It was only because the country was more concerned in the fate of the *Oregon* that the brilliant service of the gunboat was overshadowed by the work of the battleship, and thus the feat of the *Marietta* in reaching the blockading line in practically perfect fighting trim never received the recognition that should have been accorded the smaller of the two war vessels that came from the Pacific to battle with Cervera's fleet.

Since the termination of the Spanish-American war this vessel has made a cruise to China and the Philippines. In the waters of the latter she was under way most of the time for a year. During the last eighteen months she has cruised almost continuously in West India waters, between ports where it is not possible to make machinery repairs on shore or to purchase engineering supplies. Probably no vessel in the Navy during the past five years has steamed as many miles, for the *Marietta* has logged over 80,000 knots during that period.

SMALL AMOUNT OF REPAIRS.

During these years of service the boilers very seldom required the assistance of any other help than that of the ship's force.

The following is a list of repairs made since she has been commissioned, by other than the ship's boilermaker and his helpers:

(a.) Renewing fire-brick around fronts of furnace with cast-iron liners at Boston Navy Yard, July, 1899.

(b.) Renewal of ash pans at Boston, July, 1899; Portsmouth, October, 1901, and New York, June, 1902.

(c.) Retubing feed heaters, Boston, July, 1899.

(d.) Replacing seventeen tubes of feed heater, New York, June, 1902.

(e.) Renewing a small portion of the casing, New York, June, 1902.

(f.) Renewing lagging on steam drum and pipes about the boilers.

The renewal of much of this lagging might be more properly charged to repairs to piping, since it formed no integral part of the boiler.

On board large warships, where it is possible to carry spare material, every one of the repairs that were made at a navy yard could have been effected by the ship's force. It was simply because material was not available that such repairs were not made on board the gunboat *Marietta*.

PRESENT CONDITION OF BOILERS.

The boilers are now in good condition, and everything about them in general is working well. They have not received any special care, but, on the contrary, have had unusual and severe service. No special precautions have been taken to insure a supply of perfectly pure water, although the fact has been fully appreciated that purity of feed is essential in the operation of all water-tube boilers. Salt water sufficient to bring the saturation in the boilers up to $\frac{1}{32}$ has been used; the ship has cruised at full speed many times for several days with this saturation without any bad results at the time nor afterwards. However, every effort was made to maintain a fresh feed at all times. At no time has a long period been required for repairs. No rupture of tubes or headers has taken place, nor has there been any dangerous overheating.

Considering the fact that the *Marietta's* installation of water-tube boilers was one of the first of this type to be put into any war vessel, and that she has had no firemen specially trained in the management of marine steam generators of this design, the results secured are more than satisfactory.

DRYNESS OF STEAM GENERATED.

Dry steam seems to be furnished under the severest of conditions. Priming has never occurred. Whether the ship is rolling, the feed water dirty, fires forced or caustic soda admitted for neutralizing the acids, the quality of the steam seems unimpaired. The carrying over of water into the cylinders has never been noticed, and therefore practically never anticipated by the force on watch, and no separator is fitted.

NO AUTOMATIC FEED REGULATORS NECESSARY.

Even when the boilers are forced at short notice, a steady water level has been very easily maintained. The supply of feed water is therefore regular, and involves neither mental strain nor physical exertion upon the part of the water tenders. This regular supply of water has been secured without the installation of any automatic devices for regulating the flow. The boilers are fed by two vertical simplex pumps. For feed purposes a pump is kept in continuous operation, and by varying its speed the output is regulated. Within narrow limits the supply is regulated by the check valves at the boiler.

EFFICIENCY OF THE BOILER.

The boilers are efficient, about 2¼ pounds of coal per horse-power being required for general purposes. This includes the operation of auxiliaries, and auxiliaries on all warships are extremely wasteful. The smaller the ship the more wasteful the auxiliaries, since they are installed in all manner of inaccessible places and form a greater percentage of the total power. As overhauling of auxiliaries badly installed is difficult and vexatious, even important repairs are only attempted when absolutely

necessary. When measured upon the basis of the amount of water evaporated, the efficiency of the boiler varies from 60 to 70 per cent. of the very best trial conditions. This evaporation cannot be compared, however, with trial results where picked coal is used and other conditions conducive to economy prevail. On board the warship, where emergency orders often require the commander of the vessel to coal at night, when all manner of worthless fuel may be forced upon him, where coal is finely broken up by numerous handlings and where a mixture is often used, the results attained on board the *Marietta*, as regards efficiency, are good, and will compare well with actual results secured under any other type of marine boiler.

ARRANGEMENT AND SIZE OF THE FURNACES.

By reason of the fact that each boiler has but a single furnace, although the firing is done from three doors, the output of the boiler decreases rapidly when any furnace door is open for a considerable time, such as when fires are cleaned. Where a sufficient number of these boilers could be arranged in battery, cleaning the fires should not interfere with the uniform steam supply. Fair results have been attained even from this single furnace installation. The ship has not had exceptionally skilled firemen. By persistent training expert stokers have been secured at times, and then an increased output of evaporation has been secured.

Owing to the unusual inclination of the grate from front to back, the work of firing is somewhat difficult. This labor, however, is not of a severe nature, and when the men become accustomed to the unusual arrangement of grate, good results are secured. This sloping of the grate was ordered by the Bureau of Steam Engineering, to increase the volume of the combustion chamber.

The temperature of the boiler room in the hottest weather at the places where the men work seldom exceeds 108 degrees. In the vicinity of the steam drum, where there is considerable piping and where new joints might have to be made, it becomes very warm.

DEFECTS MOST LIKELY TO OCCUR.

The most frequent defect encountered is leakage from the caps closing the openings over the 4-inch tubes on headers. These leaks have never been serious, though the slight resulting loss of water is annoying. It does not require particular skill to fit these caps. Experience shows it is best to dispense with gaskets in securing a joint, and to depend upon good metal-to-metal joint.

When the ship was first commissioned the caps were ground in with glass or emery, but later a special milling tool was made for facing off the seats. This tool insures more rapid and satisfactory work. After facing the caps good results have been secured by giving a coating of black lead or graphite to the joint. Where the seating is bad, and where the milling machine cannot be readily used, gaskets have been made of rainbow packing, sheet copper or oiled paper. These gaskets must be carefully fitted. The joints thus made have proved tight where skill and care have been exercised in fitting the gasket. In general, the use of gaskets should be avoided, because when they blow out the resulting leakage is much greater than the loss of water from the slightly defective metal joint.

When there is a serious leak from a cap the cause is generally the giving way of the dog. The metal around the hole in these dogs or lugs occasionally splits, and by the enlargement of the hole the cap is loosened and drops out of place to a very slight extent. This defect fortunately has seldom occurred, and with ordinary care can be detected before it becomes dangerous. Difficulty has also been experienced by the cracking of a few of the caps.

LITTLE TROUBLE EXPERIENCED WITH SCREW PLUGS.

The composition screw plugs closing the openings over the 2-inch tubes give comparatively little trouble. When it has been found necessary to renew them the work has been easily done. As these plugs are neither subjected to the action of the flame nor exposed to any undue heat, impairment is of rare occurrence. The steel headers into which these caps fit have not yet shown signs of deterioration from galvanic action.

ENDURANCE OF BOILER TUBES.

In both boilers the lower row of 4-inch tubes have been renewed twice. Such renewal has been found necessary by reason of corrosion of the lower surface of the tube just inside the front header, because there is a pocket there which collects sediment and permits of but little circulation. The impairment of these tubes was first noticed by their bending up, which tends to pull the corroded half of the tube out of the header and starts a leak at the expanded joint in the front header. The renewal of these tubes has been easily accomplished both at sea and in port. Special care has been exercised in keeping track of the condition of the tubes near the front header, so that the tube can be removed before a rupture or excessive corrosion takes place.

But very few good tubes have been found bent, almost all the latter being those which have been corroded and burnt. Practically no other leaks have occurred at the expanded joint, although the tube has been secured and made tight by an ordinary expander.

TUBES EASILY RENEWED.

None of the 2-inch tubes of the boiler have as yet shown any signs of giving out. The renewal of an ordinary tube is not a difficult job. Fires, of course, must be hauled, caps removed, the expanded end cut and bent inwards, and then the tube can be quickly withdrawn by anyone who has had experience in this repair. The renewal of any one tube does not impair the tightness of any of the others.

Cast-iron plugs for closing the ends of the tube were supplied the ship when she went into commission, but these plugs have not given satisfaction. It is much more satisfactory to put in a new tube, as reliance can be placed upon such a repair, and probably as much time would be required to fit the plug as to renew the tube. Fires have been hauled, three tubes renewed and steam gotten up again in ten hours, more than half of this time being taken up in allowing the boiler to cool and then getting up steam. About this time is required for the repair under ordinary conditions. When haste is essential the work could be done

in much less time. When a boiler is cooled the renewal of a tube can ordinarily be done in one hour.

In case a tube in the middle of the box was badly ruptured the deformation thus caused might prevent the withdrawal of the tube through the hole in the header, and thus it might be necessary to cut out a number of other tubes to permit the defective one to be dropped into the furnace. During the five years of service of this vessel there has not been a deformed tube or one with its end bent which the ingenuity and skill of the engineers' force have not removed in the ordinary way and with but little trouble.

TUBES OF THE FEED-WATER HEATER CORRODE RAPIDLY.

The tubes of the feed-water heater are most subject to corrosion, due to the presence of the air in the feed water. It has been observed that upon portions of these tubes small lumps of soft rust accumulate, and that under each lump is a pithole where rapid corrosion has occurred. The impairment of these tubes is first detected by the interior of the tube becoming rough. Once a tube ceases to be smooth its renewal may at once be anticipated.

The heater should be kept constantly filled with water, for corrosion is greatly hastened by permitting hot air to accumulate in the upper portions. The burning of the tubes is also liable to occur if there is any failure to keep the heater filled.

The tubes of the two heaters were renewed after the first two years' service of the ship. Practically all the tubes now in the heater have been there three and a half years. Whatever renewals have taken place since 1899 have been due to the tubes having become very hot.

The life of the tubes of the heater is longest when the appliance is in continual use. It is the intermittent or non-use of this auxiliary which hastens corrosion. When the boiler is not in use the heater should either be kept perfectly dry or completely filled with water.

In order to decrease the corrosion of the heater tubes, lime has been used in the feed-water heater. By giving a very fine coat-

ing of lime to the surface of the tubes it is believed that the rapidity of air corrosion can be checked. As the feed-water heater has been installed in the uptake, increased efficiency has been secured by its use. And yet, by reason of its location, it collects much dirt. It is very inaccessible for repair and cleaning, and has proved itself in general a rather annoying and troublesome appendage. Though not a part of the boiler, it is an auxiliary which has contributed to economy in coal consumption.

BAFFLE PLATES NEED RENEWAL.

By reason of long use and the excessive heat to which they are subjected, the baffle plates are badly warped. The baffle plates of corrugated sheet metal resting on the lower row of 4-inch tubes are burnt away to a large extent. The upper layer of baffle plates is likewise impaired, but not to the extent of the lower ones. The renewal of the badly warped lower layer can only be done by cutting out some of the 4-inch tubes and by removing portions of the casing.

Soot is liable to collect on the baffle plates, and it has not been found an easy matter to remove the accumulations thus formed. An air service has been installed for getting rid of this soot, but though not effective, it is better than nothing. A steam lance has also been used for getting rid of the deposit when under way, but this has not proved effective. The soot can only be satisfactorily and completely removed when fires are hauled, and then by the use of bars and brushes followed by the use of the steam lance when pointed by some one within the furnace.

BOILER CASING NEEDS RENEWAL.

The casing consists of firebrick and asbestos, protected by thin metal plates. Up to the present time the firebricks have given little trouble. The brick linings of the furnace fronts have been replaced by cast-iron ones, which are renewed about once a year. The asbestos lining of the casing is now beginning to crumble, and considerable renewal is necessary. Some of the firebrick on the sides of the boiler are burnt out.

The metal plates of the casing, particularly around the lower

part of the boiler, now require extensive repairs. The lower portions of the supporting plates and channel bars show signs of considerable corrosion, due to the action of soot, ashes and bilge water. As much of this material is difficult to reach, and thus the preventing of corrosion has been impossible, the renewal of the greater portion of the channel bars would be extremely advisable, and they should be made of heavier iron.

THE AVERAGE STEAMING PERFORMANCE OF THE BOILERS.

Probably no better testimony could be given as to the actual performance of the boilers than to state that under favorable conditions as high a rate of evaporation can now be secured as when the boilers were new. The official logs will show that this declaration can be sustained. Under natural-draft conditions, for a period of eight hours, and with only the regular steaming watch stationed in the fire room, the boilers recently furnished to the engines over 80 per cent. of the contract trial power—an amount actually exceeding the original designed power. The fuel used was Pocahontas coal that had been mined over a year previously, and which, in the meantime, had been exposed for a considerable period to wind and weather. The coal consumption during this run was 2.22 pounds per horsepower for the propelling engines and 2.39 pounds per I.H.P. for all purposes.

The following data is taken from official logs for six hours, August 11, 1902:

Speed, knots	11.9
Sea	Smooth.
Wind	Bow.
Grate surface, square feet	94
Heating surface, square feet	3,664
Coal per hour, pounds	2,045
Revolutions, engines	starboard, 200.45; port, 200.48
Steam in boiler	starboard, 172 ; port, 172
Steam at engines	starboard, 170 ; port, 170
Vacuum	starboard, 21 ; port, 20
Horsepower	starboard, 421.25; port, 414.25
Total horsepower	853.5
I.H.P. per square foot of heating surface	.221
Pounds of coal per I.H.P. for all purposes	2.39

Pounds of coal per square foot of grate surface	21.75
Temperature, feed, degrees Fahrenheit	128
injection, degrees Fahrenheit	82
discharge, degrees Fahrenheit	116
engine room, degrees Fahrenheit	130
fire room, degrees Fahrenheit	108

The auxiliaries in operation included the dynamo, steering engine, three ventilating blowers, ash hoist and the following pumps: Air, circulating, feed, bilge, sanitary and the auxiliary air and circulating.

It will be noticed that a very poor vacuum was obtained, due to the fact that the performance was made in hot weather, when the injection water was very warm.

AVERAGE PERFORMANCE OF BOILERS FOR FIVE MONTHS, WHILE CRUISING IN THE TROPICS.

During the past five months, using Pocahontas coal obtained at San Juan, Kingston, Trinidad and Curacao, running at speeds varying from 9 to 12 knots, encountering smooth to moderate seas, and, with an ordinary fire-room force, the average performance has been as follows:

Speeds 9 to 10 knots: coal per indicated horsepower, for all purposes, 2.5 to 2.31 pounds.

Speed 10 to 12 knots: coal per indicated horsepower, for all purposes, 2.9 to 2.41 pounds.

Using half maximum power: coal per indicated horsepower, for all purposes, average 2.45.

Using three-quarter maximum power: coal per indicated horsepower, for all purposes, average 2.75.

As in the case of all small gunboats, the auxiliaries are necessarily wasteful, due to the manner in which they are installed. From actual experiment the auxiliaries used from 250 to 350 pounds of coal per hour. Deducting the amount used for auxiliaries, and only taking into account the amount of coal used by the main engines, the following average results are obtained:

Speed, 9 to 10 knots: coal per I.H.P., 1.9 to 2.3 pounds; average, about 2.15 pounds.

Speed, 10 to 12 knots: coal per I.H.P., 2.3 to 2.8 pounds; average, 2.49 pounds.

The evaporative efficiency from and at 212 degrees Fahrenheit is from 8.5 pounds to 10 pounds of water per pound of coal, giving a boiler efficiency of from 60 to 70 per cent.

When both boilers are in use and about 1,000 H.P. is developed, the make-up feed averages about four to five tons of fresh water per day. The evaporator installed (capacity 1,600 gallons per day) not only supplies all the make-up feed, but insures a liberal allowance for ship's use.

DANGER FROM SCALE.

The tubes are likely to become impaired by the presence within them of air, oil, dirt or scale. Scale is the evil that should be most dreaded, since if care is exercised the introduction of dirt or oil should be prevented. Since the water tender can give a dose of salt feed at any time, and as he will certainly give such a supply rather than run the risk of getting low water, some salt water undoubtedly goes into the boiler every day. It also may come from leaky valves. The auxiliary feed pump is the only pump fitted for pumping fire-room bilges. If, however, from any cause considerable scale is allowed to deposit, the tubes are liable to burn out. If even a thin deposit forms, the evaporative efficiency is reduced. From salt alone no serious results need be apprehended, but no salt water ever enters without carrying some scale.

ILL EFFECTS IN DIRT.

The efficiency of the boiler is likewise lessened when there is even a slight coating of dirt in the tubes. A deposit of considerable thickness will produce conditions that will result in the burning out of the tubes. Skill in management and judgment in blowing down will prevent muddy sediment from collecting in the tubes. This sediment ought even to be kept out of the water legs, which portions, however, are not subject to the action of flame or severe heat. If dirty water is used, it is imperative to blow down regularly, so that dangerous accumulations of

sediment cannot form. The mud-leg cap seats are corroded, due to sediment that has been allowed to remain.

OIL IN ANY BOILER A MENACE TO ITS SAFETY.

The strictest precaution should be taken to prevent as little oil as possible from reaching the tubes. As it is absolutely impossible to keep the tubes entirely clear of oil, since the oilers will pour oil into the auxiliaries, especially the feed pumps, even if they are sparing at the main engines, some means must be taken to neutralize its ill effects. This can be done by the use of caustic soda, the amount required being determined by special conditions.

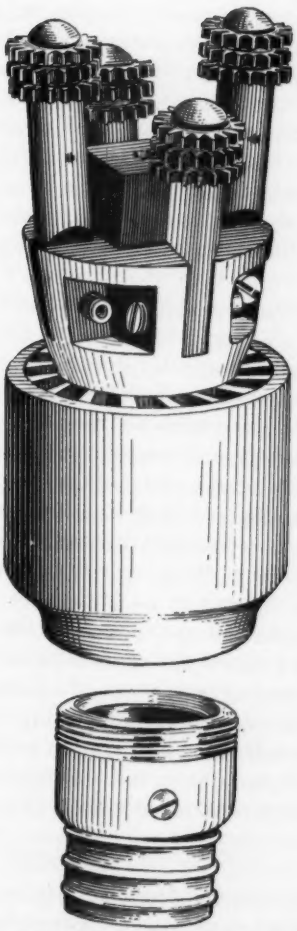
On board the *Marietta* about four pounds of caustic soda was used per week. It is also advisable occasionally to boil out the tubes by a strong solution of soda. Another way practiced on board this ship of getting rid of oil is to introduce about ten pounds of soda into the boiler, then get up steam quickly. After allowing the alkaline water in the boiler to stand for a time and thus neutralize the acid, the surface blow valve should be slightly used, and then the boiler should be emptied by means of the bottom blow valve. Where fresh water is scarce there will naturally be a disinclination to resort to this remedy.

Another way is to pump the boiler about one-third full of fresh water and then enter the soda. Admit a little steam through the auxiliary stop valve to heat the contained water. Then circulate the water through the boiler by means of an auxiliary pump, using any available auxiliary to effect this object.

It is regular and uniform cleaning, and not intermittent attention, which will insure efficiency and safety. The use of zincs is also advisable, the number and location of the baskets or slabs being dependent upon experiment, experience and character of the water.

MECHANICAL METHOD OF CLEANING INTERIOR OF TUBES.

The coating of the interior of the tubes of marine boilers is likely to occur, no matter how great the precautions that may be taken. From known and unknown causes the deterioration



TURBINE TUBE CLEANER.

and pitting of condenser tubes takes place very rapidly in certain waters, and therefore condensers leak. Through carelessness in manipulating valves, and possibly through neglect to keep valves tight that communicate with the sea, scale-forming substances are admitted into the boiler, with the depositing of scale on the tubes as a consequence.

When the interior of the tubes thus becomes coated to any extent, either with sediment or scale, and this deposit cannot be removed by the introduction of caustic soda or petroleum, the cleaning must be done by mechanical means. It is not only a long and tedious, but oftentimes an impossible, task to clean the tubes of scale with wire brushes and scrapers.

There has recently been supplied to this vessel a turbine tube cleaner, and with this tool the tubes can be effectively cleared of scale. The water supply for operating this little turbine is supplied from the auxiliary feed pump through a small hose. The arms carrying the cutters are thus made to revolve by the strong impulse (100 pounds pressure) of the water. The appliance is then shoved back and forth through the tubes. The spray of water discharged from the turbine washes away the deposit that has been loosened by the cutters. A 4-inch tube turbine cleaner requires three men to operate it—one to stand by the pump and two men to guide the tool.

It should be impressed upon the water tenders that such care should be taken in regard to the character of the feed that there will be no need of using such a tool as a turbine tube cleaner. It is a task of considerable magnitude for the ship's force to clean all the tubes of a water-tube boiler, since a very large number of joints will have to be remade, and a small amount of leakage is liable to occur from such joints after such extensive cleaning is completed.

SUMMARY OF ADVANTAGES.

(a.) *Simplicity.*—In regarding simplicity as a primary or salient feature of the boiler, it should be understood that there should be first of all simplicity of design. Any steam generator which possesses attachments whose operation is not thoroughly understood nor completely under the control of a water tender who has

not absolute confidence in their working, is certain to give trouble and prove inefficient for sustained sea work. Then there should be simplicity of construction. Finally there must be simplicity of operation, for that boiler will soon burn out which practically requires the undivided attention of one skilled man simply to look out that a safe water level is preserved.

(b.) *Dryness of steam.*—Dry steam has been furnished the engines under all manner of trying conditions. Both muddy and salt water have been used for considerable intervals, and a high gauge of water has been carried in emergencies, especially when getting under way, without producing serious results or causing priming.

(c.) *Reliable feed maintained.*—A steady and reliable feed can always be maintained. It does not require a specially trained or highly paid water tender to look out for things in the fire room.

(d.) *Simple tubes used.*—The tubes are of simple, straight lengths, care being taken to use the highest quality of material in their manufacture. Any attachment to a boiler tube invites trouble if it does not make it dangerous. As the tubes are straight they are very accessible for examination. Each tube can be moved independently of the others, and renewal can be made with ease by the ordinary ship's mechanics using simple tools.

(e.) *Rapidity of raising steam.*—Steam can be raised quickly and fires suddenly hauled without subjecting the boiler to undue strain. The fires can also be rapidly forced without any ill effect to the working parts.

(f.) *Superior material used.*—All the material used in construction is of superior quality. As an example, one of the feed-water heater tubes was reduced by being burned to a thickness of 34 B.W.G. in one place, and yet this tube resisted a pressure of 200 pounds per square inch from the interior.

(g.) *Its economic efficiency.*—The efficiency of the boiler will compare with that of any other marine water-tube steam generator. Under forced-draft conditions, also, its economic efficiency will compare favorably with any straight-tube boiler.

(h.) *Efficient circulation.*—The circulation of the water is natu-

ral and direct, and is not affected by the roll or pitch of the vessel. The endurance of the boilers of the *Marietta* ought to afford direct evidence as to the circulation of the water within the tubes. As the tubes are of large size, there is a continuous and reliable flow of water through them. The arrangement of the elements is such that the expansion of any one tube is uniform. As provision has been made for the proper expansion of the several elements, a leaky tube or joint is of very rare occurrence.

(i.) *Accessibility for repair and examination.*—Practically all the vital parts are accessible for repair and examination. The cost of upkeep is comparatively small. With the exception of the headers, all the parts are procurable from many engineering supply establishments.

SUMMARY OF DEFECTS.

(a.) *Baffling should be improved.*—The liability of the baffling to burn out, and the disadvantage if not the danger resulting from the excessive accumulation of soot upon these baffle plates, has necessitated much annoying work, besides a great loss in efficiency. The removal of the lower baffle plates cannot be done without cutting out some of the tubes.

(b.) *The feed-water heater an incumbrance.*—By reason of the manner in which the feed-water heater is installed the rapid corrosion of tubes cannot be prevented, and some are also liable to burn out. This heater is also very inaccessible for repairs and examination. It is not an integral part of the boiler, but simply an auxiliary that was placed in the uptake in order to increase the efficiency of the boiler.

(c.) *Arrangement of grate bars.*—The inclination of the grate bars practically renders the back end of the furnace useless for burning coal, because ashes will accumulate there on account of the difficulty of the firemen cleaning that portion of the grate so far removed from the furnace door. The details of furnace design are neither conducive to efficiency nor to good firing. The inclination of the grate makes stoking difficult and laborious. The combustion chamber is too small. The location of the baffle plates draws the product of combustion to the front of the

furnace, thus making it almost impossible to clean the back portions of the grate bars.

(d.) *Design of casing.*—Various portions of the casing are too light for the purposes intended. Some parts are almost inaccessible for examination, cleaning and repair. The outboard casing of each boiler comes within a few inches of the bunker bulkhead, and thus the condition of these side casings is difficult to note. By reason of the ash-pit doors and the front casings not being tight but little forced-draft pressure can be carried, and when it is used the casings and uptake soon become red hot. By reason of the leakage of this front casing, the cleaning of soot from the tubes cannot be efficiently done.

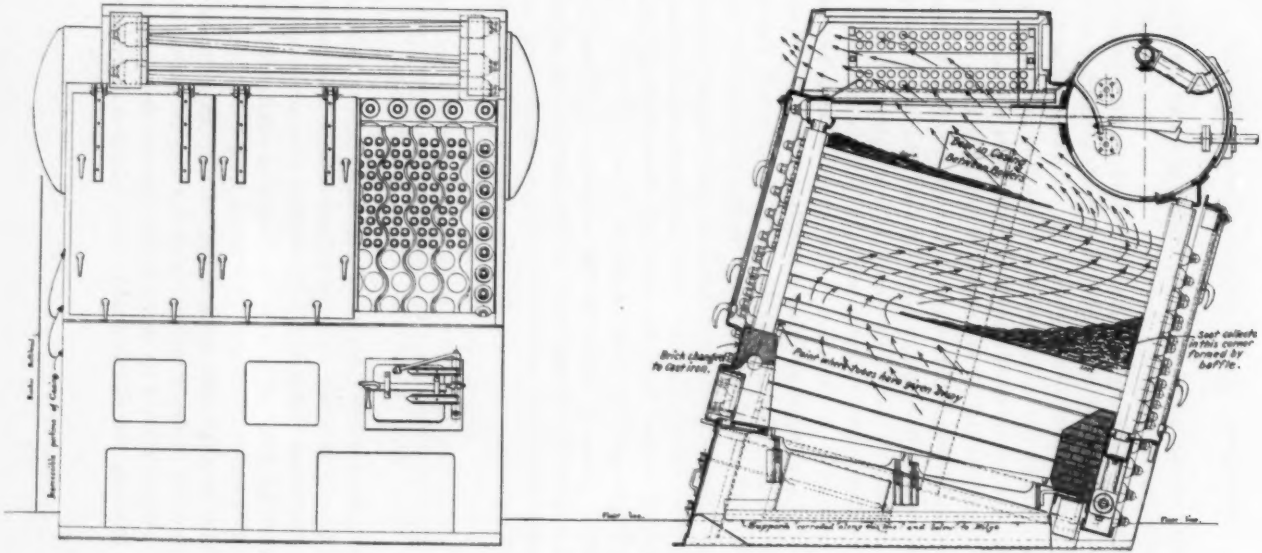
(e.) *Location of steam drum.*—The steam drum is attached to the back of the boiler, and this arrangement makes it extremely difficult for the water tenders and firemen to reach the valves that should be within easy access of repair and operation. Whenever men have to operate appliances at great discomfort and inconvenience, it is certain that such attachments will not receive the care that should be given them. It is even inviting danger to install appliances in such manner.

(f.) *Arrangement of caps.*—As the caps over the 4-inch tubes are so arranged that the pressure in the boiler tends to impair the joint, small leaks frequently occur from careless fitting of the plugs. It therefore requires skilled and intelligent men to fit the plugs.

PROGRESSIVE IMPROVEMENTS HAVE BEEN EFFECTED DURING THE PAST FIVE YEARS IN BABCOCK & WILCOX BOILER DESIGN.

In considering the defects of the *Marietta's* installation, it should be remembered that the boilers of that vessel were designed over seven years ago. Since that time progressive improvement has been effected in the details of construction of the marine boiler of the Babcock & Wilcox design.

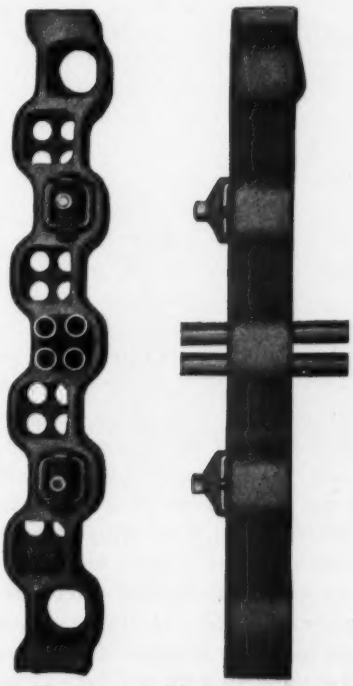
In order to show the exact nature of the advancement that has been made in the construction of this type of boiler, a careful comparison should be made of the general drawings of the boilers fitted in the *Marietta* with those which will go into the



BOILERS OF U. S. S. "MARIETTA."

new battleships which are known generally as the *Alert* type. It will be noticed that particular attention has been paid to overcoming the special defects encountered on the *Marietta*.

It will be seen that vertical baffles are now used, thus preventing the accumulation of soot. The grate bars slope from back to front, or are horizontal, thus making it easier work for the stokers to fire efficiently. The casing has been made heavier, and care has been taken to prevent any leakage of smoke. The steam drums are now placed in front of the boiler, and all its attachments are in plain sight and can be easily operated by the water tender. The header caps are now so fitted that the pressure in the boiler tends to keep the caps tight.



FORGED-STEEL HEADER AND HANDHOLE COVERING GROUP OF FOUR 2-INCH TUBES.

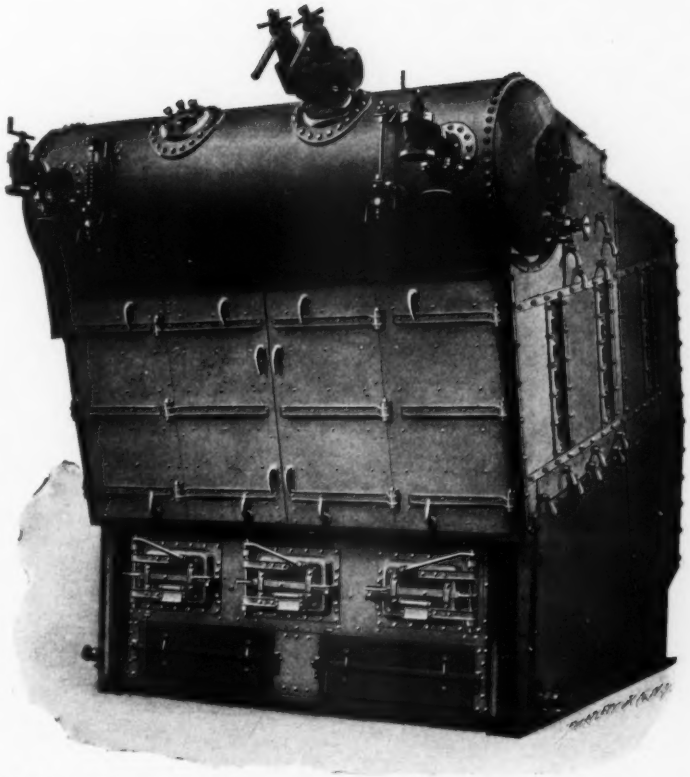
As the installation of this type of boiler in the battleships and armored cruisers now under course of construction will permit more height to be secured than was possible on the *Marietta*, a higher efficiency and increased endurance will be secured from the later design.

OBSERVATIONS AND SUGGESTIONS AS TO THE DESIGN, CONSTRUCTION AND OPERATION OF NAVAL BOILERS OF THE STRAIGHT WATER-TUBE TYPE.

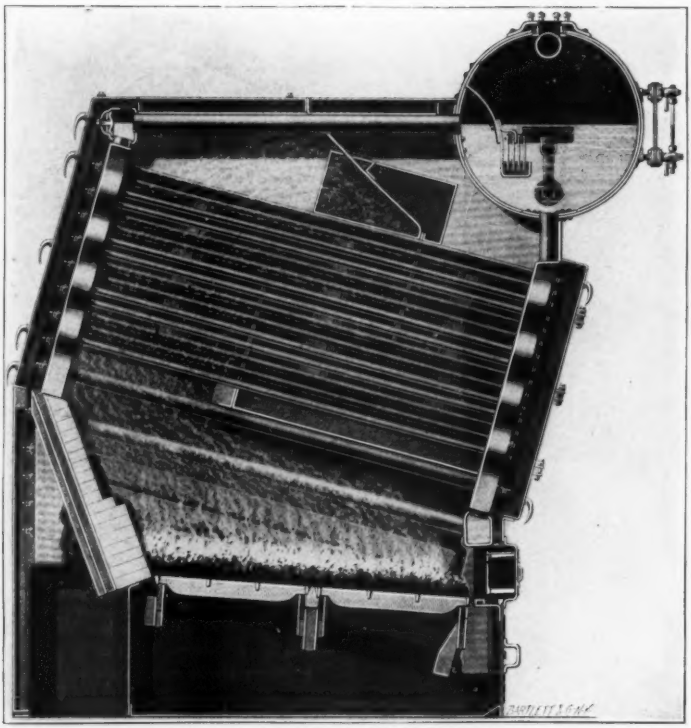
As chief engineer of the *Marietta*, there have been impelling reasons which made it incumbent upon me to familiarize myself with the merits and weakness of the Babcock & Wilcox boilers as installed in this ship. As the advantages and disadvantages of the design could only be appreciated by noting the performance of rival boilers, I have made special efforts to find out the merits and weaknesses of other straight-tube water-tube boilers by conferring with the chief engineers of the ships in which they are installed. I have found that the engineer officers of foreign navies have likewise considered the boiler problem as one of the most important within the domain of engineering. They have, therefore, been making a special study of the question, and are bent upon finding the best of the several types, so that they could be adopted in their own navy as the one of approved design. While the views herein set forth are not founded upon personal, practical experience of an extended nature, they still reflect, in great part, the judgment of men who have not only had experience, but excellent opportunity for passing upon the rival designs.

Simplicity must be one of the cardinal features of the naval boiler of the future. As the crews of warships may be changed at short notice, since such transfer often takes place when a ship is ordered to a foreign station, it is highly probable that an absolutely untrained fire-room force might be called upon with less than a few days' experience to operate water-tube boilers. This has occurred on the *Marietta* three times. Under such conditions it ought not to excite surprise if complicated designs of boiler should prove unsatisfactory and dangerous.

Endurance is an essential attribute. This does not simply

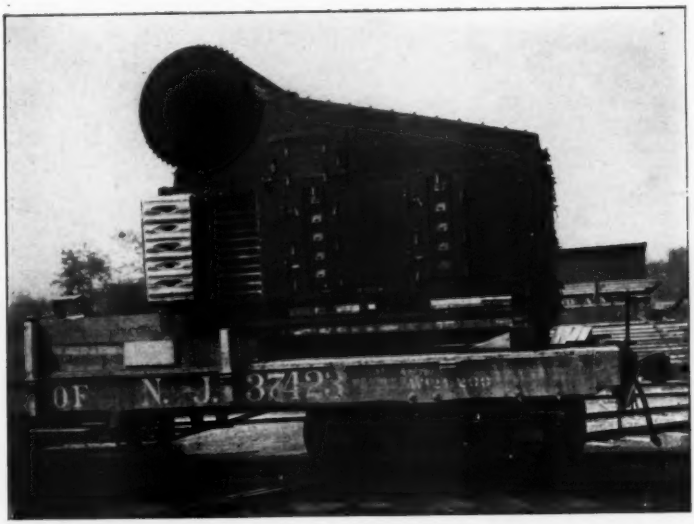


ONE OF FOUR BABCOCK & WILCOX BOILERS BUILT FOR U. S. S. "WYOMING."
PATENTED.



"CINCINNATI'S" BOILER—BABCOCK & WILCOX "ALBERT" TYPE. SECTION SHOWING PATH OF GASES.

IMPROVED BABCOCK & WILCOX BOILERS.
VIEW OF FURNACE FROM BRIDGEWALL, SHOWING ABSENCE OF FIRE BRICK IN SIDE WALLS AND BETWEEN FIRE DOORS.



SIDE VIEW, SHOWING FACILITIES FOR CLEARING SOOT FROM TUBES.

mean the ability to work satisfactorily for a long period, but rather the power to withstand forcing, to endure some neglect and to possess a reserve factor of strength that will inspire confidence in the minds of those who are intrusted with its management as to the safety of the boiler when subjected to undue conditions.

Neither the efficiency nor the capacity of the boiler should be dependent upon the reliable working of separators, reducing valves or automatic feed devices. The manner in which chief engineers of vessels throw out of use steam and water traps ought to be conclusive evidence as to the reliance that should be placed upon automatic devices. Because an appliance works efficiently on shore, where there are no limitations as to the manner in which it should be installed, it does not follow that the same device will perform equally well at sea, where the conditions as to installation are entirely different. It may even be that these devices will work all right when operated on shore by exceedingly skilled and highly paid experts, while on a war vessel their management would have to be intrusted to a fireman or petty officer. Even on official trial trips, where the test continues for a fraction of a day, and when the vessel is filled with the contractors' experts, the device may work satisfactorily for that period. On several trial trips the contractors have refused to use automatic feed devices, though installed on the boiler. When the more severe and continued tests of actual service are encountered the automatic device may prove utterly unreliable.

All complicated parts, such as intricate castings, unusual forms of tubes, special joints, or parts that require special tools for renewal are dangerous elements, particularly on board a warship which may be called upon for blockading and for cruising duty, when it will be difficult, if not impossible, to secure duplicates of the intricate parts.

MORE SEA EXPERIENCE REQUIRED OF DESIGNERS OF MARINE BOILERS.

It is because many designers have but little knowledge of the crowded manner in which marine boilers and their auxiliaries are installed that they continue to force into naval vessels complicated boilers which can only be operated, even on shore, by

specially trained men. Even to operate these boilers on shore for a fraction of the day it is essential that the manufacturers should be prepared to ship at immediate notice duplicate parts of every fitting and attachment.

In connection with this subject it may be of interest to recall the remarks made by Messrs. J. & A. Niclausse in reply to a criticism of their boiler made by Herr Von Jaski, of the German Navy, published in the February, 1902, number of the JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS. Messrs. Niclausse state in their reply that the trouble was due to the fact that the parts of the boiler were not put in place by their special tools in a special manner. The complaint was also made that the supervision of construction of the particular boilers was not made by one of the boiler company's experts.

It is reasonable to presume that both the system of technical education and apprenticeship at trades is as thorough in Germany as anywhere else in the world, and that the mechanics of that nation are artisans of skill and intelligence. In fact, there are people who believe that certainly, as respects technical education and apprenticeship indentures, Germany leads the world.

The fact that the Niclausse boilers are of such design and construction that they could be put together in the wrong way is presumptive evidence that the type is not fitted for naval needs. The complaint about these boilers does not come from Germany alone. There is some well-founded testimony to the fact that considerable trouble has been experienced on board the Russian naval ships with these steam generators. On board one naval vessel it was attempted to take down the header, and it required just as many days to do the job as it was expected it could be done in hours. The great weakness of this boiler will undoubtedly be found in the back end of the tube, due to the fact that it will be a very difficult matter to clean that portion of the tube, while it is the very part where nearly all the dirt and grease is liable to collect. The use of a small water turbine cannot be employed in cleaning out these tubes owing to the fact that only one end of the tube is open, and therefore there is liable to be an accumulation of deposit of a dangerous nature at the closed end of the tube.

In the design of the Niclausse boiler there has been too much striving upon the part of manufacturers to make boiler-shop tests and trial-trip tests the standards of performance. One might almost think that the boilers were constructed principally for the purpose of deriving data that could not be secured in practice and of securing trial-trip performances that it is not possible to duplicate in actual service.

BOILER TESTS SHOULD BE MADE UNDER ACTUAL SEA-GOING CONDITIONS.

The generally-discussed tables of comparison of various types of water-tube boilers are, as a rule, compiled from tests that cannot possibly be as severe as that to which the boilers will be subjected when installed on board a warship, where they are crowded beneath the protective deck, and where their operation is often conducted under enervating conditions. The utility, efficiency and durability of marine boilers should only be determined by extended and sea-going tests, for boilers that might stand the test of brief experimental work might become disabled under actual sea-going conditions where experts are not always at hand to assist the regular fire-room force.

On board the warship that boiler tube is a source of weakness which has a lantern or end attachment which might be wrenched off either in the insertion or removal of a tube. When one takes into consideration the fact that comparatively few men can acquire the sea habit, and therefore capable boilermakers will always be scarce at sea, simplicity of design becomes a cardinal feature in insuring efficiency.

Any boiler designed for working with absolutely fresh water, picked coal, efficient and reliable auxiliaries, expert care, and whose workmanship in some respects is like that of a watch, can hardly be expected to possess endurance. If, in addition to all these requisites, it is essential that uniform and expert stoking be done by the firemen, and that incessant care and watchfulness is essential upon the part of the water tender, it is certain that a low if not dangerous water level will inevitably be the result. If it is also imperative that special tools must be used in effecting particular repairs or doing necessary overhauling, then one

is safe in predicting that such a steam generator is not likely to possess much endurance under the actual conditions that it will experience at sea at the hands of a strenuous stoker. The boiler for war purposes is one that can stand some neglect and some of the improper treatment that it will surely receive in actual service where untrained firemen and coal passers must be intrusted at times with responsible duties.

The use of special tools for boiler work is particularly objectionable. When work is carried on at sea upon boilers it is likely that there will be a pile of ashes and soot in the fire room, and it is very likely that, through the carelessness of some fireman or coal passer, the special tool might go overboard with the refuse. It is not altogether improbable that some evil-disposed person or one nursing an imaginary wrong might throw the tool overboard.

Provision must be made for gathering the sediment that is always bound to be produced in a boiler and conducting it away from the parts subject to the direct heat of combustion. This dirt should naturally flow to some place where it can be easily gotten rid of, and any boiler that cannot be entirely drained by opening a blow-off or drain cock at the bottom will be extremely difficult to keep clean when it is not most carefully and gently handled.

Too often but little attention is paid to the tightness of the casing. Its construction is very likely to receive a secondary consideration.

In order to secure endurance a marine boiler must be capable, at least for a time, of being operated even when dirt, oil or scale-producing substances are contained in the feed water. That naval boiler will soon reach the scrap heap, or be removed out of the warship by reason of its unsuitableness, whose feed supply can not be maintained within comparatively large limits by an ordinary pump operated by a fireman of average ability.

U. S. S. "WYOMING."

CONTRACT TRIAL OF THE U. S. S. *WYOMING.*

By Lieutenant W. W. Bush, U. S. Navy.

The *Wyoming* is a twin-screw, single-turreted monitor, built by the Union Iron Works of San Francisco, Cal., being one of the four harbor-defense vessels whose construction was provided for by Act of Congress approved May 4, 1898.

The contract was signed on October 5, 1898, the vessel to be completed in twenty-nine months, for $975,000. Owing to difficulties in obtaining material and the strike of 1901, the date of completion was afterward extended to September 13, 1902. The penalty for overtime is $500 per day, and after six months the penalty becomes $600 per day.

The battery, ordnance outfit, armor and armor bolts, excepting those of the protective deck, anchors and chains, boats and various smaller articles of equipment, were furnished by the Government, the contractors being required to put them in place.

The speed guaranteed was 11½ knots, at a mean draught of twelve feet six inches, the air pressure in the fire rooms being limited to the equivalent of one inch of water.

No premium for exceeding the contract speed was provided for, but the following penalty was set for any failure to obtain the same, viz: $5,000 for every quarter knot, and if the speed falls below 11 knots the penalty is increased to $10,000 per quarter knot; also, it is provided that if the speed should fall below 10½ knots, it is optional with the Secretary of the Navy either to reject the vessel or to accept it at a reduced price.

The weight of machinery, including water in the boilers, condensers, pumps and pipes, is limited to 240 tons with a penalty of $500 per ton for overweight and a further penalty of $10,000 if the overweight exceeds 5 per cent.

HULL.

Length between perpendiculars, feet	252
over all, feet and inches	255- 1½
on L.W.L., feet	252
Beam, extreme, feet	50
at L.W.L., feet	50
Ratio of length to beam, feet	5.04
Depth (molded) from top of main deck beams at side to bottom of frames at midship section, feet and inches	14-11½
Height of superstructure above main-deck beams to bridge deck, feet and inches	7- 8
Draught, normal, mean, feet and inches	12- 6
Displacement corresponding to normal draught, tons	3,218
Displacement per inch at L.W.L., tons	25.4
Area of immersed midship section, square feet	597
L.W.L. plane, square feet	10,670
Center of gravity of L.W.L. plane aft of midship section, feet and inches	3- 4⅝
Center of buoyancy above bottom of keel, feet and inches	6-11
forward of midship section, feet and inches	3- 1½
Transverse metacenter above center of buoyancy, feet and inches	16- 9½
Longitudinal metacenter above center of buoyancy, feet	398
Coefficient of fineness on extreme dimensions	.715
of midship section	.954
L.W.L.	.847
Cylindrical coefficient	.750
Number of frames	82
watertight compartments	148

The hull is constructed of mild steel of domestic manufacture with frames spaced three feet apart. The ship is divided into 148 watertight compartments. The watertight doors on the berth deck and those leading into dynamo room, fire room, coal bunkers and passages, are operated by the long-arm system, with pneumatic power, controlled from the pilot house. There are in all twenty-three doors operated on this system. The double bottom extends from frame 6 to frame 77. There is a military mast just abaft the conning tower and pilot house, in which are mounted two 1-pounder automatic guns. On a platform above the top is the forward searchlight.

Bridge Deck.—On this deck is located the pilot house, three 6-pounder semi-automatic, and four 1-pounder automatic guns, the after searchlight and the boats. Two 26-foot cutters are

carried in cradles, one each side, aft, and one 28-foot steam cutter, one 28-foot launch and two 28-foot whaleboats are carried at the davits. An 18-foot dinghy is stowed inside of the launch. There is a double steam winch on this deck for hoisting the boats.

Superstructure Deck.—On this deck are located four 4-inch rapid-fire guns, arranged at the corners of the superstructure so as to give the forward guns an angle of fire of 135 degrees, and the after ones 165 degrees. There are also two 1-pounder automatic guns, one each side, aft the conning tower, the galleys and the drying room.

Main Deck.—On this deck, forward of the superstructure, is the 12-inch turret and the windlass. Within the superstructure are the lavatories, showers, a large portion of the crew's space, cabin, officers' quarters, wardroom, logroom, and offices of the executive officer and paymaster.

Berth Deck.—On this deck are the sick bay, machine shop, storerooms, berthing space for a portion of the crew, dynamo room, staterooms of the captain and wardroom officers and the steering room. There is a wing passage on both sides of the ship, on this deck, extending from the dynamo room aft the starboard one to the wardroom, and the port one to the steering room.

Hold.—Below the berth deck are the magazine, shellrooms, storerooms, coal bunkers and boiler and engine spaces. There are twelve coal bunkers, with a total capacity of 380.6 tons, at 43 cubic feet to the ton.

Drainage System.—The main drain is of galvanized steel 11 inches in diameter, and runs from the boiler room to the engine room, having branches in the engine room connecting it with each circulating pump. It is also provided with connections to the fire and bilge and auxiliary feed pumps, and is fitted with the necessary non-return valves. For the auxiliary drainage four manifolds are fitted in convenient places, with suction pipes leading to the double-bottom compartments, trimming tanks and sea connections required. All manifold valves are worked from the manifolds direct.

Armor.—The water-line belt is vertical and extends the entire length of the ship, two feet six inches above and two feet six inches below the water line. In wake of the engines, boilers and magazines the armor is eleven inches thick on top and tapers to five inches at the armor shelf. Forward and aft of this the thickness is reduced to seven inches at the top and four inches at the shelf, while at the extreme ends of the ship the top and bottom thicknesses are five and three inches, respectively. The conning tower is seven and one-half inches thick, and there is an armored tube three inches thick leading from it, carrying telegraphs, wheel ropes, &c. The smoke pipe and ventilator have armor five inches thick, extending four feet above the main-deck armor. The main-deck armor is one and a half inches thick, and consists of two 30-pound plates. The barbette for the 12-inch guns has armor eleven inches thick in front and nine inches in rear. The front plate of the turret is inclined, and is ten inches thick; the other turret plates are nine inches thick.

Armament.—The battery consists of two 12-inch, Mark III, breech-loading rifles, mounted in a balanced turret, on the center line of the ship, forward of the superstructure; four 4-inch, Mark VII, rapid-fire guns, mounted in the superstructure; three 6-pounder, semi-automatic rapid-fire; four 1-pounder (heavy) automatic; two 1-pounder Hotchkiss, heavy, Mark II; two Colt's automatic, 30-caliber, mounted in and upon superstructure and in the military top.

MAIN ENGINES.

There are two three-cylinder triple-expansion engines of the vertical, inverted, direct-acting type, placed opposite each other in the same watertight compartment, the H.P. cylinder of each being forward. The cylinders of each engine are supported by three front and three back columns; the front columns are of forged steel of cylindrical section, and the back columns are of cast iron, cast in with the condenser sections.

The bedplates are of cast steel, and consist of six cross girders of I section and one longitudinal girder of ∩ section, with stiffening ribs.

The H.P. valve chest of each engine is fitted with one piston

valve, the I.P. valve chest with two piston valves and the L.P. valve chest with a double-ported slide valve. The L.P. valves only are fitted with balance pistons.

The link motion is of the double-bar Stephenson type, all valves being worked direct, with one crosshead for the I.P. valves.

Independent adjustable cutoffs are fitted to each link with a range of from four-tenths to seven-tenths stroke.

All cylinders are jacketed around the working linings.

The throttle valve of each engine is balanced by a piston working in a cylinder forming part of the throttle-valve casing, steam being admitted to the back of the balance piston by means of a by-pass pipe and valve. The throttle valves are operated by latch levers with worms and quadrants.

The main and auxiliary steam pipes are of lap-welded mild steel; auxiliary steam pipes of less than two inches diameter are made of copper.

The lubricating system consists of a distributing tank for each engine with pipe connections to the manifolds furnishing oil to the moving parts of each cylinder. The distributing oil tanks are filled by a hand pump from the main storage tanks.

The main pistons are of cast steel, dished, and are finished all over. Each piston is packed with two packing rings set out by steel springs. The piston rods are hollow, of forged nickel-steel, oil tempered and annealed, three and three-fourths inches outside diameter and one and three-fourths inches inside.

The connecting rods, with their caps and bolts, are of forged nickel-steel, oil tempered and annealed. An axial hole, two inches in diameter, is bored through the entire length of each rod. The crosshead end of each rod is forked to span the crosshead, the wrist pin being shrunk in and secured from turning by screw keys.

The body of the crosshead is forged on to the piston-rod end, and a manganese-bronze slipper lined with anti-friction metal is bolted to its under side.

The crosshead guides are of cast iron, and are secured to the back columns. The guides are cored out on the backs and fitted

with steel plates to form passages for the circulation of the cooling water. The backing guides are also of cast iron, and are bolted to flanges provided for that purpose on the go-ahead guides.

The eccentrics are of cast iron, made in two parts and bolted together on the shaft. Each backing eccentric is securely keyed on the shaft, and each go-ahead eccentric is secured to the corresponding backing eccentric by a through bolt in a slotted hole.

The eccentric straps are of composition faced with white metal, and the eccentric rods are of forged steel.

There is for each engine a steam float-lever reversing engine, with hydraulic controlling cylinder, the piston rod of the steam and hydraulic pistons being the same. A pump is provided, connected with the hydraulic cylinder for reversing by hand.

The turning engine is a double, inverted, 4 by 4 by 4 engine, driving a worm shaft, which in turn drives a second worm, which may be made at will to mesh with a worm wheel on either propelling shaft. The turning engine is made reversible by means of a change valve. A ratchet wrench is fitted for turning the engines by hand.

ENGINE DATA.

Cylinders, number for each engine	3
H.P., diameter, inches	17
I.P., diameter, inches	26½
L.P., diameter, inches	40
Stroke of piston, inches	24
Valves, H.P. (one for each cylinder), diameter, inches	9
I.P. (two for each cylinder), diameter, inches	9
Valve stems, H.P. (1), diameter, lower ends, inches	2¼
through valve, inches	1¼
I.P. (2), diameter, lower ends, inches	2¼
through valve, inches	1¼
L.P. (1), diameter, lower ends, inches	2½
through valve, inches	1¾
at balance piston, inches	1⅜
Main steam pipe, diameter, inches	5½
exhaust pipe to condenser, diameter, inches	13½
Piston rods, diameter, inches	3¾
length from piston to center of crosshead pin, inches	45⅜

Piston rods, axial hole, inches	1¾
Connecting rods, center to center, inches	48
diameter, upper ends, inches	3¾
lower ends, inches	4¼
axial hole, inches	2
crosshead bolts, diameter, inches	1⅞
crank-pin bolts, diameter, inches	2
Wearing surface ahead, square inches	131½
back, square inches	100
Crosshead pins, diameter, inches	4¼
length in bearing, inches	8½
Reversing gear, steam cylinder, diameter, inches	8
controlling cylinder, diameter, inches	4½
Crank shafts, diameter, inches	7½
axial hole, diameter, inches	4¼
coupling discs, diameter, inches	14½
thickness, inches	2
bolts in one flange (6), diameter, ins., taper	2 to 1⅞
Crank-shaft journals, diameter, inches	7½
length, inches	9
axial hole, inches	4¼
Crank webs, width, inches	8¼
thickness, inches	4¼
Thrust shaft, diameter, inches	7½
coupling disc, diameter, inches	14½
thickness, inches	2
axial hole, inches	4½
length, feet and inches	9-9
collars, number, each shaft	9
diameter, inches	11½
distance between, inches	2½
thickness, inches	1½
Surface, total, both engines, square inches	967.28
Propeller shaft, diameter, inches	7½
axial hole, inches	4½
outboard length	...
total length, feet and inches	44-7½

Shafting and Bearings.—The crank shafts are of forged steel, each being made in two sections, the forward section having two cranks and the after section one crank. When the sections are bolted together the cranks are 120 degrees apart, and in the ahead motion their sequence is H.P., I.P., L.P. There is a 4¼-inch axial hole bored through shaft and pins. The propeller shafts are

fitted with a composition casing from inboard of the stern-tube stuffing boxes to the propeller hubs.

The thrust bearings are of the collar type; the pedestals and caps are of cast iron, the side and end walls forming an oil trough in which there is a copper cooling pipe. At each end there is a bearing five inches long, lined with white metal. The collars are nine in number. An oil box is cast in the cap, from which the oil is led to the collars, and at each end is a divided stuffing box and gland to prevent the escape of the oil. There are four screw bolts, two at each end, for adjusting the bearing fore and aft.

Main Condensers.—There is a condenser for each main engine, made in two parts, of cast iron, and forms part of the engine framing. The tube sheets and tubes are of Muntz metal. Baffle, circulating and tube-supporting plates are fitted. The circulating water passes through the tubes. There are 913 tubes in each condenser, of $\frac{5}{8}$-inch outside diameter, and No. 18 B.W.G. thickness. The cooling surface of each condenser is 1,612 square feet.

Main Air Pumps.—For each main engine there is one vertical, bucket air pump, worked by link and beam connection from the L.P. crosshead. The air-pump cylinders are $16\frac{1}{2}$ inches in diameter and $8\frac{1}{2}$ inches stroke. The air pump valves are made of composition.

Main Circulating Pumps.—There is a double centrifugal-inlet circulating pump for each condenser, driven by a $\frac{4\frac{1}{2} \times 9}{6}$ compound engine. Each pump is arranged to draw from the sea, the main drain and the engine-room bilge, and will deliver into the condenser or overboard direct. All suction valves are connected by a locking device, so that when one is open the others must be shut. The inlet and outlet nozzles are of 8 inches diameter.

Auxiliary Condenser.—There is one auxiliary condenser, located in the engine room. The tubes, sheets, ferrules and packing are of the same sizes and materials as those of the main condensers. It has a vertical combined air and circulating pump of the Dow

pattern, with steam cylinder 6½ inches diameter, circulating pump 8 inches, air pump 10 inches, and stroke 10 inches. The cooling surface is 455 square feet.

Feed-Water Heaters.—There are two feed-water heaters located in the fire room. They are similar in construction to condensers, and are situated between the pumps and the feed main. Each has a tube-heating surface of 130.7 square feet. The valves are so arranged that the feed water may be by-passed, or passed through the heater; also so that the auxiliary exhaust steam, which is the heating agent, may be passed into the heater, the condenser or the second receiver at will.

SCREW PROPELLERS.

The screws are rights-and-lefts, three-bladed, built-up, true screws, bent back 5 inches, of manganese-bronze. The top tips of the blades turn inboard in the ahead motion. Each boss is secured by two feather keys, and a wrought-steel nut is screwed on and locked in place. The end of the hub is covered by a watertight composition cap. The blades, hubs and caps are tinned. The pitch is adjustable from 7 feet 8.6 inches to 9 feet 4.4 inches, and for the trial the pitch was set at 8 feet 5.9 inches.

Number of blades	3
Diameter, feet	8
of hub, inches	26¼
Length of hub, inches	23
Pitch, as set, feet and inches	8-5.9
Greatest width of blade, inches	39½
Helicoidal area of each screw, square feet	25.8
Projected area of each screw, square feet	21.18
Disc area of each screw, square feet	50.26
Pitch ÷ diameter	1.0614

BOILERS.

There are four boilers, of the Babcock and Wilcox type, of the usual marine construction, and are designed for a working pressure of 250 pounds per square inch. There is a reducing valve in the main steam pipe which reduces the pressure to 200 pounds at the engines. The boilers are placed with furnaces athwartship. Each boiler is fitted with a combined self-closing

and automatic 4½-inch stop valve, with horizontal spindle fitted with automatic and hand-controlling device, closing toward the boiler in case of accident to the boiler, and against the engine in case of accident to the main steam pipe beyond the stop valve. The safety valves are twin valves of 3 inches diameter. In each boiler are 392 tubes 2 inches diameter and No. 8 B.W.G. thickness, and 34 tubes of 4 inches diameter and No. 6 B.W.G. thickness. The tubes are seamless, of steel, and cold drawn. The steam drums are of steel, 36 inches internal diameter, ½ inch thickness and 9 feet 4 inches long. The grate surface for one boiler is 50 square feet, heating surface 2,200 square feet. The furnaces are 6 feet long and are fitted with sprays for extinguishing the fires in case of accident. There is one smoke pipe 6 feet 2 inches internal diameter, the top of the pipe being 70.8 feet above the grates.

Forced Draft.—The closed fire-room system of forced draft is used, the air being supplied by two blowers of Union Iron Works design. The fans are each driven by a compound engine $\frac{4\frac{1}{2} \text{ inches by } 8 \text{ inches}}{4\text{-inch.}}$ The diameter of the fan is 57 inches, area of induction nozzle 712.76 square inches, area of eduction nozzle 1,016.64 square inches. The capacity of each blower is about 8,682 cubic feet per minute at a pressure of ½ inch of water.

Feed Pumps.—There are two main feed pumps in the fire room and two auxiliary feed pumps in the engine room. They are all of the same size and type—Dow single-cylinder, vertical, steam cylinder 8 inches, water cylinder 5 inches, stroke 10 inches. Each main feed pump is arranged to draw water from the communicating pipe between feed tanks and the reserve feed-water tanks, and will deliver into the main feed pipes and reserve feed-water tanks.

The auxiliary feed pumps are arranged to draw water from the communicating pipe between feed tanks, the boilers, the sea, the main drain pipe, drainage manifolds, and the engine-room bilges at will, and will discharge into the boilers, the fire main, the distiller circulating pipes and overboard.

Fire and Bilge Pump.—There is a Dow vertical, single-cylinder pump in the engine room, 7 inches by 7 inches by 12 inches, which is arranged to draw water from the sea, the engine-room bilge, the main drain and the drainage manifolds, and to discharge into the fire main and overboard.

Water Service Pumps.—There is in the engine room a Dow vertical, single-cylinder pump, 7 inches by 7 inches by 12 inches, having a suction from the sea only, and which will deliver into the engine-room water-service pipes, into the fire main and into the distiller circulating pipes.

Hotwell Pumps.—In the engine room are two Dow vertical, single-cylinder pumps, 5½ inches by 5½ inches by 8 inches, that are arranged to draw water from the hotwell tanks and deliver the same into the entrance chamber of the feed and filter tanks. These pumps are also furnished with suctions from the air-pump channel ways, from the traps of the feed-water heaters, from the side of the ship above the water line for taking in fresh water for the boilers, and from the reserve feed tanks; they have also a discharge pipe to the reserve feed tanks.

Main Bilge Pumps.—The main bilge pumps are worked by an eccentric from the main engine shafts, there being one on each shaft. They are inclined plunger pumps, with water cylinder 4½ inches in diameter and 5 inches stroke. These pumps draw from crank pits, and discharge overboard.

Feed Tanks.—There is a combined feed and filter tank for each engine, each having a capacity of 340 gallons. They are fitted with the usual pipe connections. There are also reserve feed tanks of 40 tons capacity.

Hotwell Tanks.—Each main air pump has a hotwell tank with a capacity of 65 gallons. Each tank has the following connections: a branch from the main air-pump discharge, a branch from the auxiliary air-pump discharge, a suction pipe from the bottom of the tank to the hotwell pump, and a 3-inch connecting pipe between the tanks.

Engineers' Work Shop.—The work shop is provided with the following tools: a 14-inch back-geared, screw-cutting lathe, a column-shaping machine, a double-geared drilling machine, and a 12-inch emery grinder. These tools are fitted up with the

necessary counter shafts, pulleys and belts, and are driven by a 6 by 5 vertical engine with Pickering governor.

Ash Hoists.—There is one 4 by 4 by 6 ash-hoisting engine of Union Iron Works design, arranged to hoist ashes up the fire-room ventilator. With steam pressure of 80 pounds, 300 pounds of ashes can be hoisted in 5 seconds.

Distilling Apparatus.—The distilling apparatus is located in the after part of the fire room. It consists of two evaporators and two distillers, with their accessories. The evaporators are arranged so that they may be operated in double effect, and each have a capacity of 2,600 gallons per twenty-four hours. Upon a test each distiller showed a capacity of 2,900 gallons of water at a temperature of 88 degrees Fahrenheit per twenty-four hours. The evaporator feed pump is a horizontal Dow pump, steam cylinder $4\frac{1}{2}$ inches, water cylinder $2\frac{3}{4}$ inches, stroke 6 inches, and is piped to feed both evaporators. The circulating water for distillers is supplied by the engine-room water service or auxiliary feed pumps. There is a combined fresh-water and brine pump of the Dow horizontal type with steam cylinder 3 inches, fresh-water cylinder $2\frac{1}{8}$ inches, brine cylinder $2\frac{1}{8}$ inches and stroke 3 inches. The fresh-water pump is piped to pump distilled water from each distiller to the fresh-water tanks, and to the main-feed and reserve-feed tanks.

Ventilating Fans.—The ventilating fans are operated by electric motors, and are eleven in number, distributed over the ship where necessary. The particulars of these motors are given in the list of motors.

Steering Engine.—In the steering room there is a combined hand and steam-steering engine of the Union Iron Works design, vertical, two cylinders, 6 inches diameter and stroke 6 inches The engine is controlled from the conning tower and pilot house with wire rope.

Steam Windlass.—A steam windlass of Union Iron Works design is located forward on the main deck. The engine is reversible, double cylinder, direct acting, with cylinders 8 inches diameter and stroke 10 inches. The windlass is fitted with two wild cats.

Steam Winch.—On the bridge deck are two double-cylinder horizontal winches of Union Iron Works design for hoisting boats. The cylinders are 5 inches diameter and stroke 7 inches.

Air Compressor for Long-Arm System.—On the berth deck forward of the dynamo room on the starboard side is the air compressor for operating the twenty-three watertight doors that belong to the long-arm system. It is vertical, three cylinders, of 2, 3¾ and 7¾ inches diameter, with 6 inches stroke, and is driven by a 7½-horsepower electric motor.

Telegraphs and Revolution Indicators.—There is a repeating mechanical telegraph of Union Iron Works design for each engine, connected to transmitters in the conning tower and pilot house. There is also a gong for each engine with bell pulls on deck. Mechanical telltales showing the direction of motion of the main engines are fitted in the conning tower and pilot house, and in addition to these are two electrical indicators of the illuminated-dial pattern, with transmitters in the pilot house, for use during fleet maneuvers.

Voice Tubes and Telephones.—For communication between the various parts of the ship there is a complete system of voice pipes and telephones provided with the necessary call bells. The stations are directly connected, there being no central station.

ELECTRIC PLANT.

The installation consists in general of about 275 incandescent lights, two searchlights, one night-signal set, one main switchboard, consisting of generator, light and power sections, one searchlight switchboard, together with all wire, conduit molding, wiring accessories and fixtures.

The four generating sets were constructed by the Union Iron Works. Each set consists of a thirty-two kilowatt, four-pole, compound-wound dynamo, direct connected to a cross-compound, vertical, inverted-cylinder engine. The diameters of the cylinders are 8½ inches and 13½ inches, the length of stroke 8 inches, and the speed 400 R.P.M. at full load with 100 pounds steam pressure. The bedplate is common to both engine and dynamo. Each of the dynamos is connected to the main switchboard, and

may be operated either independently or in parallel with the others.

The switchboard carries the busbars for the various sections, viz: lightning, power, searchlight and turret turning. Each dynamo can be connected, when required, to either or all of these sections.

The ship is wired on the two-wire system.

The searchlights were made by the General Electric Company. One is mounted on a platform on the mast above the military top, and the other aft on a platform on the bridge deck. The projectors are 24 inches in diameter and are hand controlled. The lamps are of the horizontal type, with combination hand and automatic feed, and are designed for a current of about 50 ampères with a difference of potential of about 48 volts across the arc.

The carbon holders are adjustable and the life of the carbons is approximately six hours.

The signal set is the Boughton telephotos, and consists of four double signal lanterns and a pivoted keyboard, this last being on top of the pilot house. Electric speed indicators are fitted in the pilot house and conning tower, also electric helm indicators and electric steering engine telegraphs.

There are mechanical thermostats in each coal bunker and in certain storerooms, with an annunciator on the bulkhead outside of the captain's office.

ELECTRIC MOTORS.

Name.	Number	I.H.P.	R.P.M.	Volts.	Ampères.
Turret turning	2	18	400	80	200
12-inch ammunition hoist	2	20	312	80	220
12-inch elevating	2	3.5	400	80	45
12-inch rammer	2	5	775	80	60
4-inch and 6-pounder chain ammunition hoist	4	2.5	750	80	30
No. 7 ventilating fans	3	4.5	878	80	50
No. 4 ventilating fans	2	1.5	1,400	80	18
Whip-hoist motor	6	2.5	1,200	80	30
No. 5 ventilating fans	1	1	886	80	12
Smoke blower in turret	1	5	1,800	80	6
Air-compressor motor of long-arm system	1	7.5	960	80	90

OFFICIAL TRIAL.

The official trial was made by the standardized screw method. Four points of the speed and revolution curve were determined by making a double run for each point, over a measured mile course in San Francisco Bay. The revolutions per minute necessary to give a speed of 11½ knots were found from this curve, and the vessel was taken outside the bay for a two-hours' run in the open sea.

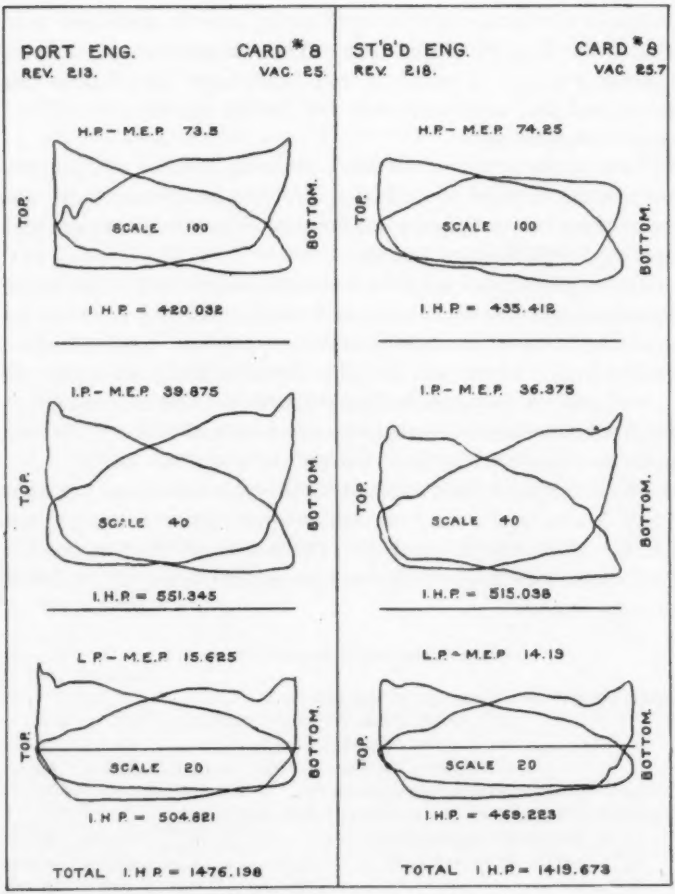
The standardization trial took place on October 28, and the sea trial on October 29. During the two-hours' trial there was a moderate sea on the port quarter, and considerable water came on board both forward and aft.

The engines raced slightly throughout the trial. The entire machinery plant worked very well, and the engines were run for over five hours continuously, at more than the required speed for the trial. There was no difficulty in making all steam required, and at no time during the trial did the air pressure in the fire room exceed five-eighths of an inch of water. The coal used was Harris navigation (Cardiff), of excellent quality.

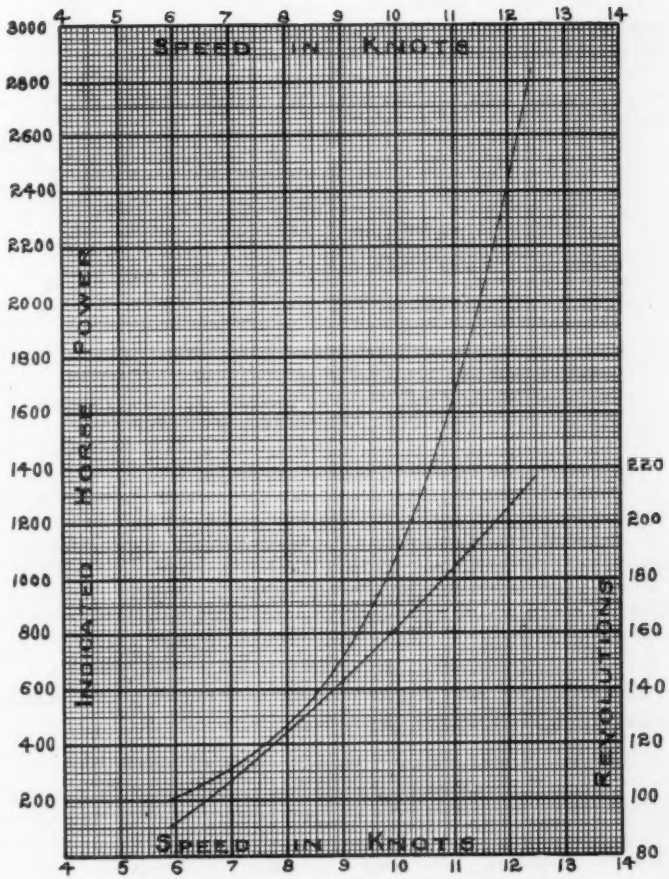
The maximum speed attained on the standardization runs was 12.37 knots, with 214.7 revolutions per minute and 2,811.01 I.H.P. The average speed upon the two-hours' trial at sea was 11.8 knots, with 201.3 revolutions per minute and 2,325.71 I.H.P. of main engines.

PERFORMANCE—SYNOPSIS OF STEAM LOG.

	Starboard.	*Port.*
Steam pressure at boilers, per gauge, pounds	227	
H.P. steam chest, per gauge, pounds	215	218
1st receiver, absolute, pounds	64	68
2d receiver, absolute, pounds	21	23
Vacuum in condensers, inches of mercury	27	26
Mean effective pressures in cylinders of main engines:		
H.P., pounds per square inch	80.125	78.187
I.P., pounds per square inch	28.391	30.969
L.P., pounds per square inch	10.516	12.219
Mean pressure on L.P. piston, equivalent to aggregate M.E.P. on all pistons, pounds per square inch	36.691	39.147
Revolutions per minute, main engines	200.3	202.3



MAXIMUM POWER, U. S. S. "WYOMING."


SPEED IN KNOTS
INDICATED HORSE POWER
REVOLUTIONS
SPEED IN KNOTS
4 5 6 7 8 9 10 11 12 13 14
3000 2800 2600 2400 2200 2000 1800 1600 1400 1200 1000 800 600 400 200
220 200 180 160 140 120 100 80

U. S. S. "WYOMING."

	Starboard.	*Port.*
Revolutions per minute, pumps, air	200.3	202.3
circulating	219	219
feed, double strokes	75	
Blower engines, mean revolutions	491	
Speed of ship in knots per hour	11.8	
Slip of propeller in per cent. of its own speed, based on mean pitch	29.72	30.42
Air pressure in fire room in inches of water	$\frac{3}{8}$	
Indicated horsepower, main engines:		
H.P.	430.675	424.548
I.P.	369.237	406.797
L.P.	319.519	374.935
Auxiliary condenser, air and circulating pumps, estimated	3	
Circulating pump, estimated	5	5
Feed pumps	22.98	
Water-service pump and all auxiliaries in use, estimated	10	
Blower engines for forced draft in fire room, estimated	50	
Dynamo engines	30	
Collective of all main engines and air pumps	2,325.711	
air, circulating and feed pumps	2,358.691	
Collective of all machinery in operation during the trial	2,451.691	
Main engines, air, circulating and feed pumps, per square foot grate surface	11.793	
Heating surface, square feet per I.H.P. (2,451.691)	3.588	
Cooling surface, square feet per I.H.P. (2,451.691)	1.315	
Kind and quality of coal	Harris navigation, excellent.	
Coal per I.H.P. per hour (I.H.P., 2,358.691)	2.517	

The following table shows the results obtained on the standardization trials, October 28:

Double run.	Steam—		Revolutions per minute.	I.H.P.	Mean speed in knots.
	At boilers.	At engines.			
No. 1	178	176.5	91.5	211.55	5.97
2	183	170	134.2	589.99	8.57
3	210	200	170.5	1,295.50	10.4
4	242	201.75	214.7	2,811.01	12.37

SECOND OFFICIAL TRIAL U. S. S. *WYOMING*, SAN FRANCISCO BAY, OCTOBER 28, 1902.
Trials Over Measured Mile for Standardizing Screws.
Fire-room data on this sheet taken by B. & W. men. Mercurial gas filled pyrometer in uptake. Uptake and other

SECOND OFFICIAL TRIAL U. S. S. *WYOMING*, SAN FRANCISCO BAY, OCTOBER 28, 1902.

Trials Over Measured Mile for Standardizing Screws.

Fire-room data on this sheet taken by B. & W. men. Mercurial gas filled pyrometer in uptake. Uptake and other temperatures taken by Government officials.

Time.	Steam pressures at boilers.				Air pressure in fire room	Draft, Boiler B.		Fire-room temperatures.									Uptake temp., therm.	Temp. of deck above fire room.	Temp. engine room.	Temp. of feed water.
	A	B	C	D		Bot. 1st pass.	Top 3d pass.	1	2	3	4	5	6	7	8	9	10				
10·30	150	...	...	...	*	...	...	154	167	78	115	112	184	156	90	104	92	415	101	101	100
11·00	...	...	...	...	*	...	..	152	166	99	104	105	180	154	92	104	106	395	106	100	100
11·30	175	...	...	...	*	.30	...	134	156	100	105	112	178	144	85	103	110	...	...	...	100
11·50	...	...	...	...	*	...	...	137	153	100	105	107	182	142	86	102	97	445	91	...	100
12·10	200	...	...	...	*	.30	...	153	152	100	104	101	183	160	92	104	100	490	106	101	98
12·20	...	...	...	...	*	‡	...	156	162	100	106	112	184	152	87*	106	90	490	106	102	100
12·55	215	217	223	238	+ ⅜	‡	...	158	154	100	114	114	180	165	100	105	84	500	108	104	93
1·00	215	215	218	229	+ ½	‡	...	...	...	...	...	...	...	...	...	...	...	555	110	104	...
1·05	209	202	207	212	+ ⅝	‡	...	153	127	100	110	101	175	128	96	106	84	...	...	...	106
1·07½	217	223	227	236	+ 1⅛	‡	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1·10	230	227	237	240	+ $1\frac{1}{16}$	1.03	.60	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1·15	250	251	252	262	+ $1\frac{1}{16}$	...	...	150	112	100	112	107	168	118	98	102	82	525	108	...	117
1·30	...	...	...	...	...	...	...	151	110	100	103	105	172	122	98	95	78	535	107	108	118
2·30	...	...	...	...	†	...	...	153	150	100	104	110	185	160	98	100	86	490	107	...	98

* Fire room open; both blowers 115 revolutions per minute. † Fire room open. ‡ Port blower 680, starboard 780.

Feed-water heater not in use. Temperature of feed water same as hotwell.
Draught of ship 12 feet 3 inches forward, 12 feet 9 inches aft.
Displacement 3,220 tons. Two screws, 8 feet diameter, 8 feet 6 inches pitch.
Main engines $\frac{17 \text{ inches} \times 26\frac{1}{2} \text{ inches} \times 40 \text{ inches}}{24 \text{ inches}}$.
Four B. & W. boilers, each having 2,200 square feet H.S. and 50 square feet grate.
Location of thermometers:

No. 1. Midway between boilers A and B (center of fire room), 18 inches below deck.
No. 2. Two inches above casing boiler A, 2 feet from after outboard corner, 14 inches below deck.
No. 3. After part of starboard coal bunker, 12 inches from fire-room bulkhead, 2 feet below deck.
No. 4. Center of fire room, 5 feet above floor.
No. 5. Back of boiler B, 8 inches from casing, 3 inches from bulkhead, 4 feet from floor.
No. 6. Five inches below deck, near safety valve of boiler B.
No. 7. Same as No. 2, except 8 inches above casing and 8 inches below deck.
No. 8. Near center line of fire room, 2 feet from forward bulkhead, 3 feet from floor.
No. 9. Near forward inboard corner of casing of boiler C, 5 feet above floor.
No. 10. Four feet aft of boiler D, 4 feet below deck, 18 inches from port bulkhead.

Two 5-foot fans (Union Iron Works), located in after fire-room bulkhead—one each side of center line of fire room.

TABLE No. 1.—OFFICIAL SEA TRIAL U. S. S. *WYOMING*, OFF SAN FRANCISCO, OCTOBER 29, 1902.

Official data, taken by Government representatives. Displacement 3,225 tons. Draught of ship 12 feet 6 inches forward, 12 feet 9 inches aft.

Time, P. M.	Fire-room temperature. (See remarks 2d table.)			Engine-room temperatures.				Uptake temperature.	Temperature of deck over fire room.	Temperature on deck aft of conning tower.	Temperature of main deck port side funnel.	Temperature of funnel casing.	Temperature of dynamo room.	Temperature of firemen's washroom.	Temperature of hotwell.		Revolutions of port blower.	Strokes of feed pumps.
				Forward, outboard.		Aft, inboard.												
	1	2	4	S.	P.	S.	P.								P.	S.		
2'00	140	130	95	98	102	102	99	560	97	58	70	86	93	79	105	104	648	62
2'15	140	124	96	98	104	102	100	635	95	58	69	80	92	79	...	...	720	72
2'30	140	138	98	100	106	104	102	610	98	58	74	84	*92	80	100	104	610	70
2'45	142	154	99	100	106	103	101	635	97	57	74	93	93	81	...	...	620	68
3'00	144	140	100	100	108	104	103	640	97	57	75	93	93	82	103	105	570	74
3'15	144	128	102	102	108	104	102	650	99	57	76	97	94	83	...	...	540	68
3'30	142	132	101	101	108	104	103	615	100	57	78	98	95	84	105	105	325	64
3'45	140	128	100	101	108	104	104	600	100	57	78	99	93	84	...	...	...	...
4'00	140	128	100	102	108	106	105	620	98	57	78	100	92	84	101	102	...	...

Cardiff lump coal used for fuel.

REMARKS BY B. & W. REPRESENTATIVE.—Trial made in heavy sea; course of ship altered repeatedly. Very little smoke from funnel. Uptake temperature (base of funnel) measured by mercury pyrometer. Temperature of deck over fire room taken by thermometer lying on iron plate on deck, just aft of funnel.

TABLE No. 2.—DATA OFFICIAL SEA TRIAL U. S. S. *WYOMING*, OFF SAN FRANCISCO, OCTOBER 29, 1902.

Taken by B. & W. men.

Time, P. M.																		

TABLE No. 2.—DATA OFFICIAL SEA TRIAL U. S. S. *WYOMING*, OFF SAN FRANCISCO, OCTOBER 29, 1902.
Taken by B. & W. men.

Time, P. M.	Steam pressure at boilers.				Temp. feed.	Fire-room pressure.	Fire-room temperatures.									
	A	B	C	D			1	2	3	4	5	6	7	8	9	10
2'00	223	223	223	230	96	...	140	130	...	95	100	165	160	93	...	76
2'05	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2'10	...	...	...	...	...	+ .25	...	...	...	...	...	...	...	...	...	...
2'15	230	225	...	...	...	+ .88	...	...	...	...	...	...	...	...	...	...
2'20	225	223	230	235	105	+ .63	139	124	...	97	100	162	150	93	...	74
2'25	225	218	...	...	...	+ .38	...	...	...	...	...	...	...	...	...	...
2'30	238	234	...	...	...	+ .06	...	...	...	...	...	...	...	...	...	...
2'35	213	212	...	...	...	+ .19	...	...	...	...	...	...	...	...	...	...
2'40	228	224	226	224	101	+ .25	142	133	...	99	99	164	164	94	...	76
2'45	230	227	...	...	...	+ .44	...	...	...	...	...	...	...	...	...	...
2'50	222	220	...	...	...	+ .25	...	...	...	...	...	...	...	...	...	...
2'55	227	224	...	...	...	+ .06	...	...	...	...	...	...	...	...	...	...
3'00	225	220	228	235	101	+ .38	144	147	...	100	101	164	172	94	...	76
3'05	227	226	...	...	...	+ .44	...	...	...	...	...	...	...	...	...	...
3'10	225	222	...	...	...	+ .25	...	...	...	...	...	...	...	...	...	...
3'15	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
3'20	238	235	233	243	102	+ .38	144	144	...	101	103	166	177	94	...	76
3'25	226	223	...	...	...	+ .63	...	...	...	...	...	...	...	...	...	...
3'30	222	222	...	...	...	+ .31	...	...	...	...	...	...	...	...	...	...
2'35	237	232	...	...	...	+ .31	...	...	...	...	...	...	...	...	...	...
3'40	222	220	220	230	100	+ .19	142	127	...	99	98	165	142	94	...	76
3'45	235	230	...	...	...	+ .38	...	...	...	...	...	...	...	...	...	...
3'50	227	228	...	...	...	+ .38	...	...	...	...	...	...	...	...	...	...
3'55	230	227	...	...	...	+ .38	...	...	...	...	...	...	...	...	...	...
4'00	225	225	224	231	100	+ .25	141	128	...	99	100	164	157	94	...	76

Feed-water heater not used. Temperature of feed same as in hotwell. Air pressure in fire room very variable.

LOCATION OF THERMOMETERS.—No. 1. Midway between boilers A and B, center of fire room, 18 inches below deck.....No. 2. Two inches above casing boiler A, 2 feet from after outboard corner, 14 inches below deck.....No. 3. Same as No. 2, except 8 inches above casing and 8 inches below deck.....No. 4. Between boilers A and C, 5 feet from floor. .....No. 5. Midway between boilers A and B (center of fire room), 18 inches below deck.....No. 6. Near center line of fire room, 2 feet from forward bulkhead, 3 feet from floor. .....No. 7. Back of boiler B, 8 inches from casing, 3 inches from bulkhead, 4 feet from floor.....No. 8. Four feet aft of boiler D, 4 feet below deck, 18 inches from port bulkhead.....No. 9. Five inches below deck, near safety valve boiler B.....No. 10. Near forward inboard corner of casing of boiler C, 5 feet above floor.

TWO-HOURS' TRIAL IN THE OPEN SEA.

Time.	Revolutions per minute.		Mean.
	Starboard.	Port.	
2'05	...	...	...
2'20	200.7	199.7	200.2
2'35	203.4	201.3	202.35
2'50	201.4	203.7	202.55
3'05	199.9	202.5	202.2
3.20	199.6	203.3	201.45
3'35	198.5	202	200.25
3'50	199.7	203	201.35
4'05	199	202.5	200.75

The mean revolutions for the two hours were 201.3, corresponding to a mean speed of 11.8 knots, with 2,325.71 mean I.H.P. of main engines and air pumps.

	Starboard.	*Port.*
Mean pressure of steam at boilers, per gauge	226.8	
engines	214.8	219.6
1st receiver	64.31	67.64
2d receiver	21.33	21.86
Vacuum	26.13	26.96
Maximum air pressure in fire room, inch		$\frac{4}{8}$
Mean air pressure in fire room, inch		$\frac{3}{8}$

CONTRACT TRIAL OF U. S. MONITOR *NEVADA*.

By W. S. Newell, Associate.

The *Nevada* is one of the four single-turreted harbor-defense monitors contracted for in October, 1898. This monitor was built and engined by the Bath Iron Works, and is a sister ship to the *Arkansas*, *Wyoming* and *Florida*. With the exception of the boilers, the *Nevada* is practically identical to the *Wyoming* as regards hull, engines and equipment, a complete description of which may be found in the present number.

BOILERS.

Four Niclausse boilers are installed in one watertight compartment, the fire room being athwartships and the passageway to the engine room aft and the firemen's wash room forward, running fore and aft along the center line of the ship between the boilers. The working pressure for these boilers is 250 pounds. They are composed of nineteen elements, each of which has thirty $1\frac{9}{16}$-inch and four $3\frac{3}{4}$-inch generating tubes.

Air heaters are placed above the boilers in way of gases as they leave the generating tubes on their passage to the uptakes.

Dimensions of One Boiler.

Height, to top of steam dome, feet and inches	10–$9\frac{1}{8}$
boiler casing, feet and inches	7–$2\frac{1}{8}$
Width (external), feet and inches	12–3
Length (external) fore and aft, feet and inches	8–5
Steam drum, length, feet and inches	11-$6\frac{1}{4}$
inside diameter, feet and inches	2-$7\frac{1}{4}$

	Outside diam.	*Length.*	*Thickness.*	*Number.*
Generating tubes	$3\frac{1}{4}''$	$7'-4\frac{9}{16}''$	No. 6 B.W.G.	76
.....	$1\frac{9}{16}''$	$7'-3\frac{3}{8}''$	No. 8 B.W.G.	570
total one boiler				646
Circulating tubes	$1\frac{9}{32}''$	$7'-2\frac{9}{16}''$	No. 21 B.W.G.	76
.....	$\frac{13}{16}''$	$7'-3\frac{3}{8}''$	No. 21 B.W.G.	570
total one boiler				646
Furnace doors, number				4
Air heater, surface, square feet				604.75

TOTALS FOR FOUR BOILERS.

Heating surface, square feet	8,874
Grate surface, square feet	220
Air heaters, square feet	2,419

PROPELLERS.

The propellers of this ship are three-bladed manganese-bronze of the following dimensions:

Diameter, feet and inches	9–2.7
Hub diameter, inches	24
Pitch, adjustable from, feet and inches	6-6.83 to 7–9.55
as set (mean), feet and inches	7–9.55
Disc area, square feet	66.6
Helicoidal area, square feet	24.03
Projected area, square feet	21
Distance to center of hub above lowest point of keel, feet and inches,	4–9
Top of propeller immersed at load draught, feet and inches	3–1½

The *Nevada* left Bath, Me., for Boston on November 19, 1902. The weather was overcast, a moderate sea running, and the ship's behavior at sea was such as is usual with this type; she rolled easily, but at no time was the rolling excessive. The engines turned up on an average of 145 per minute, and the vessel logged nine knots per hour on the run from Seguin Light to Boston Light.

On November 20, the monitor was docked in the Boston Navy Yard, for the purpose of scraping and cleaning, in preparation for her acceptance trial. The bottom was found to be in good condition, and, after being scraped, was painted with three coats of anti-fouling paint. The zinc protecting rings in the sea chests were also examined and found to be in good condition. At this time the propeller blades were twisted so as to increase the mean pitch from 7 feet 2 inches to 7 feet 9.55 inches.

On December 18, 1902, at 8·30 A. M., the *Nevada* left the Boston Navy Yard and proceeded to Cape Ann, where she arrived and started over the course at 11·48 A. M. The run was for a distance of 13.2 nautical miles, running north, returning over the same course, running south. The speed, uncorrected for tide, was 12.95 knots, the tidal corrections bringing the speed to 13.039 knots.

During the trial the fire room was kept open, no attempt being made to use forced draft, although for the last fifteen minutes of the run the blowers were run at a moderate speed to assist the draft.

In addition to the regular revolution counters in the engine room, temporary counters, which were readily thrown in and out of gear, were installed on the upper deck.

The coal used was picked Pocahontas of good quality. It was stowed in bags, each containing 100 pounds, so as to enable an accurate account to be kept of the quantity of coal burned.

The air heaters were not in use during the trial. The tubes heated during the latter part of the run, but at no time did they go above a red heat. The automatic feed arrangements in the boilers were not used, the contractors preferring to regulate the feed by hand.

Besides the main engines, circulating and feed pumps, the following machinery was in operation:

One water-service pump.

One bilge pump.

One combined air and circulating pump for auxiliary condenser.

One dynamo engine.

Two auxiliary feed pumps, running slowly ready for use. These were not used during the trial.

All the machinery worked well, ran cool and easily developed the power needed to drive the vessel at the contract speed.

The auxiliary exhaust was open to the second receiver.

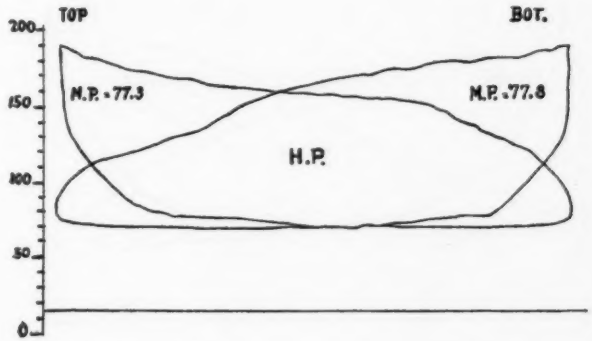
ABSTRACT FROM STEAM LOG.

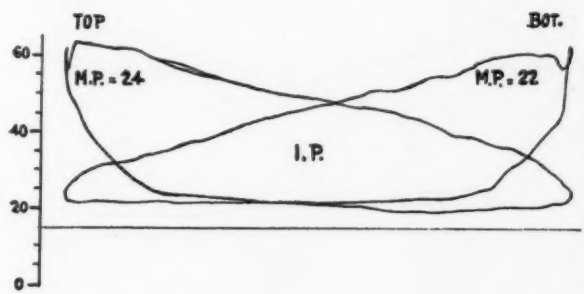
Steam pressure at boilers (gauge), pounds				238.8
engine (gauge), pounds	Star.,	184.9	port,	192.5
1st rec. (abs.), pounds	Star.,	62.5	port,	64.5
2d rec. (abs.), pounds	Star.,	18.85	port,	23.8
Vacuum, inches of mercury				27.8
Mean pressures, H.P., pounds	Star.,	72.21	port,	64.87
M.P., pounds	Star.,	23.49	port,	24.70
L.P., pounds	Star.,	11.90	port,	11.56
M.E.P. referred to L.P. cylinder	Star.,	34.75	port,	33.63
Indicated horsepower, H.P.	Star.,	361.52	port,	327.80
M.P.	Star.,	284.35	port,	301.77

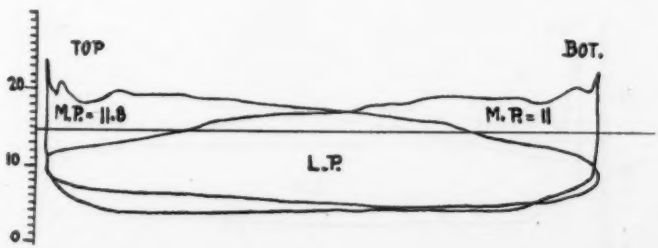
Indicated horsepower, L.P.	Star., 336.72; port,	330.21
Total for each engine	Star., 982.59; port,	959.78
Total for both engines		1,942.37
Horsepower circulating pumps	Star., 5.61; port,	6.07
Two main feed pumps		15.72
Auxiliary condenser, air and circulating pump		3.00
Water-service and bilge pump (two pumps)		7.00
Dynamo engines (one)		24.00
Revolutions per minute, main engines	Star., 186.46; port,	188.19
circulating pumps	Star., 253.2 ; port,	261.2
Double strokes per minute, main feed pumps		42.0
water-service pump		49.2
fire and bilge pump		46.9
air and circulating pump, auxiliary condenser		30.0
Speed of ship, knots per hour		13.039
Slip of propeller, per cent	Star., 9.16; port,	9.99
Collective horsepower, main engines, air, circulating and feed pumps		1,969.77
Collective horsepower, main and auxiliary engines in operation during trial		2,003.77
H.P. per square foot of G.S. (all machinery during trial)		9.11
H.S. (all machinery during trial)		.2258
G.S. (main engines, air, circulating and feed pumps)		8.95
H.S. (main engines, air, circulating and feed pumps)		.2219
Coal used per hour, pounds		5,311.
Pounds per hour per I.H.P., all machinery in operation		2.65
main engines, air, circulating and feed pumps		2.74
Pounds per hour per square foot of G.S.		24.14
H.S.		0.598
Cooling surface per I.H.P., square feet		1.65

U.S.S. NEVADA.
STARBOARD ENGINE.

Steam pressure at engines 184.9
Revolutions per minute 208.75 Vac. 27.82

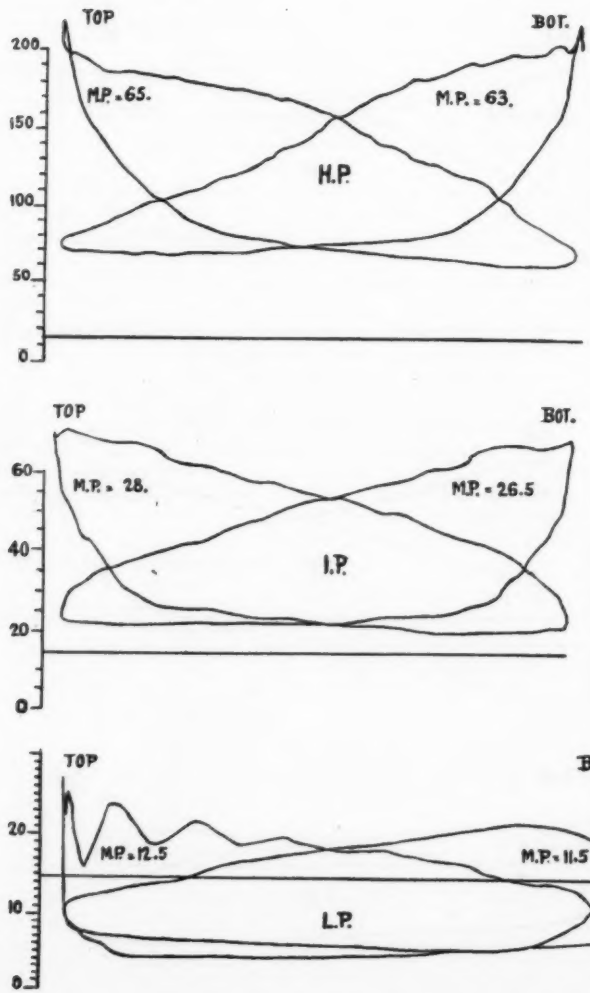


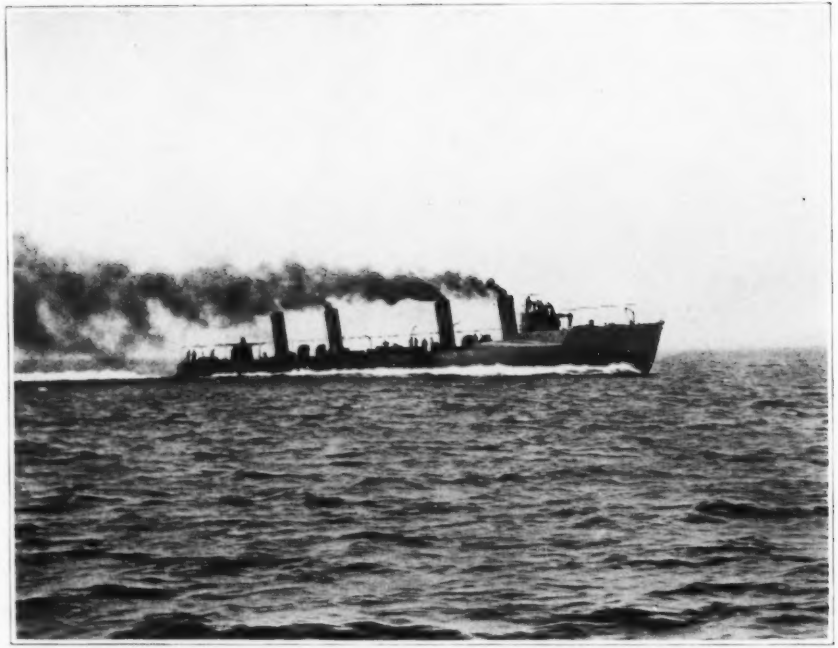




U.S.S. NEVADA
PORT ENGINE

Steam pressure at engines 192.5
Revolutions per minute 190.6 Vac 27.82





TORPEDO-BOAT DESTROYER "STEWART."

THE CONTRACT SPEED TRIAL OF U. S. TORPEDO-BOAT DESTROYER *STEWART*.

By Lieutenant Albert Moritz, U. S. Navy.

The *Stewart* is a torpedo-boat destroyer for the United States Navy, constructed by the Gas Engine and Power Co. and Chas. L. Seabury & Co., Consolidated, Morris Heights, New York City. She was designed for about 420 tons trial displacement, but her actual displacement on the official trial of October 22, 1902, was 444 tons. The displacement under service conditions will be 609.46 tons.

The contract for this boat was signed September 30, 1898. The cost, $282,000, was stipulated on a guarantee that she would develop on her speed trial 29 knots an hour for two consecutive hours.

The time allowed for completion, seventeen months, was extended by approval of the Navy Department, on account of labor troubles at the contractors' works and the difficulty in getting material.

The speed requirement was modified by order of the Navy Department in letter to the Bureaus of Steam Engineering and Construction and Repair, dated February 26, 1902, to an average speed of at least 27 knots for one hour.

This modification was the result of a request by a committee of the contractors for the construction of the torpedo boats and torpedo-boat destroyers authorized by the act of May 4, 1898, on account of extraordinary expenses incurred by them in the fulfillment of these contracts and their desire to keep down expenses. In the opinion of the writer, the modification lessened the expense of the contractors materially, because the cost of numerous preliminary trials to "tune up" was avoided.

On trial the *Stewart* made 29.26 knots for one hour at a mean

displacement of 444 tons, and did better during the second half hour than during the first half.

The same high requirements as to machinery, material, stability, and maneuvering and seagoing qualities were demanded as for all U. S. naval vessels. The materials used and the workmanship applied in the construction of the *Stewart* were of the very best quality.

The vessel, named for Admiral Charles Stewart, who won fame in the war of 1812, was launched May 10, 1902, and was christened by Miss Frances Rodney Stewart, a granddaughter of the Admiral.

HULL.

The hull is constructed of steel of domestic manufacture, the best obtainable. It is provided with two conning towers, cabin, ward room, store rooms, pantries, state rooms, magazine, water-closets, complete steering and draining apparatus and wooden signal pole. It also has an electric plant for lighting the vessel, and one searchlight.

All wood used was treated by a fire-proofing process.

The first of the flat keel plates, which are 12½ pounds to the square foot amidship and 10 pounds to the square foot at ends, was laid May 10, 1899, nearly eight months after the signing of the contract. This delay was caused by the difficulty in getting material.

The vertical keel plates are 10 pounds to the square foot, and 14 inches in depth.

There are 138 transverse frames and deck beams, spaced 21 inches from center to center.

The whole of the outside plating under water and to 1 foot above normal water line, the floor plates, bulkhead plates, reverse frames and frames to 1 foot above normal water line, vertical keel plates and bilge keel were galvanized by the hot process.

The vessel is divided into ten principal watertight compartments, transversely, viz: forepeak, crew space, forward fire room, forward engine room, after engine room, after fire room, petty officers' quarters, forward officers' quarters, after officers' quarters and tiller room.

All doors, manholes and stuffing boxes in bulkheads are made watertight.

The forward conning tower is formed of nickel-steel plates ½ inch thick; the after conning tower of steel plates ½ inch thick.

The overhead work in the officers' and crew spaces consists of very light wood frames, covered with painted canvas.

BATTERY.

The battery consists of five 6-pounders, semi-automatic, and two 14-pounders, rapid-fire guns (heavy), mounted on cage stands; two center-pivot torpedo tubes for 5-millimeter torpedoes.

In connection with the torpedoes there is a Bliss air compressor, Type 1, with a separator and strainer, with connections for charging the torpedoes at each torpedo tube. Piping connects the torpedo tubes with the air compressor, which is capable of sustaining a pressure of 1,500 pounds to the square inch. It is installed in the forward engine room, amidships on forward bulkhead. The steam line for the air compressor is fitted with a reducing valve, so as to use steam at sixty pounds pressure.

The location of the gunmounts is as follows:

Two 6-pounders on each side just abaft the break of the forecastle.

One 6-pounder amidships, port side, abreast forward engine room.

One 6-pounder amidships, starboard side, abreast after engine room.

One 6-pounder on center line forward the after conning tower.

Two 14-pounders, one on each of the conning towers.

Two center-pivot torpedo tubes, located singly, forward one on center line over bulkhead between engine rooms; after one on center line at the stern.

PROPELLING ENGINES.

The propelling engines—two sets—are of the vertical, inverted cylinder, direct-acting, triple-expansion type, each with one high, one intermediate and two low-pressure cylinders.

The order of the cylinders is as follows, beginning forward: For starboard engine—2d L.P., I.P., H.P. and 1st L.P.; for the port engine—1st L.P., H.P., I.P. and 2d L.P. The diameter of H.P. cylinder is 20½ inches; I.P. cylinder, 32 inches; 1st and 2d L.P. cylinders, 38 inches. The stroke of all pistons is 22 inches. There is one piston rod for each cylinder, the diameter of which is 4¼ inches. The H.P. cylinder has one piston valve; each of the other three cylinders has two.

The engines are designed for about 8,000 H.P. when they are making 327 revolutions. The starboard engine is placed forward and the port engine aft, and are supported by vertical forged-steel columns. The bedplates are of cast steel, crank shafts of nickel-steel, hollow and in two sections. The shafts, piston rods, connecting rods, eccentric rods and working parts in general are of forged nickel-steel.

In addition to the bracing of the engines themselves, each of the two L.P. cylinders—one at each end of each engine—has a brace attached to plate secured to top cylinder cover underneath relief valve, the other end being secured to bracket at intersection of deck beams and framing. These are made with taper pins for easy adjustment.

The valve gear is of the Stephenson type, with double-bar links. The cut-off is regulated by screw adjustments at the end of the reverse arm of each cylinder. There is a steam reversing gear, fitted with an oil cylinder to act as a dash pot and brake.

The condensers are cylindrical, of Muntz metal, steam on outside of tubes, and each having a total cooling surface of 3,469 square feet.

There are two double-acting, vertical air pumps for each engine, worked from the H.P. and I.P. crossheads.

There are four Seabury water-tube boilers. The forward one is 14 feet 5 inches long by 8 feet 9⅛ inches wide. The other three are each 16 feet 4 inches long by 9 feet 2⅜ inches wide. There are two furnaces in each boiler. The total grate surface is 315⅛ square feet; heating surface, forward boiler, 3,817 square feet; in each of the other three boilers, 4,655 square feet.

The fire rooms are arranged to be closed for forced draft.

There is one vertical centrifugal blower for each boiler. The blowers and blower engines were made by the contractors.

There are four oval smoke pipes, the heights of which, above grates, are as follows: Boiler A, 27 feet 11½ inches; B, 28 feet 4½ inches; C, 27 feet 5½ inches; D, 25 feet 3 inches. The area of forward smoke pipe is 1,246.86 square feet, that of each of the other three 1,516.86 square feet.

There are two true-pitch propellers, built solid, inclined aft, each with three blades of manganese-bronze, the starboard propeller left and the port right-handed. The pitch is 10 feet 8½ inches; diameter, 8 feet; helicoidal area of each, 23.316 square feet.

The vessel is provided with the following pumps of the Davidson pattern:

One main feed pump in each engine room and each fire room.

One auxiliary feed pump in each fire room, which may be used as fire and bilge pump and for ash ejectors.

One fire and bilge pump in each engine room, which may be used as furnace-fire extinguishers.

One distiller circulating pump and one evaporator pump in the after engine room; the distiller pump may be used for water service on main engines.

There are two ash ejectors, one in each fire room.

There are two evaporators and one distiller in after engine room with a maximum capacity of 2,160 gallons per day, and an ordinary distilling capacity of 1,500 gallons per day.

There are eight coal bunkers having a capacity of about 180.39 tons of coal.

The engine rooms are each lighted by eight fixed steamtight globe lamps of 16-candle power, and the fire rooms each by four of the same kind. Besides, there are eight portable lamps of 16-candle power each, for general use in the department.

The dynamo is of the General Electric Company, marine type, multipolar, compound, and is designed for 80 volts, 5 kilowatts and 63 ampères; is run by a Seabury engine designed for 700 revolutions. The engine is of the vertical, inverted-cylinder type; 10-horsepower; diameter of cylinder, 5 inches; stroke, 3

inches; piston valve, dynamo and engine direct coupled on one bedplate and provided with a fly-wheel governor.

There is a "Hyde" cable windlass with gypsy head, operated by double horizontal engines. Diameter of cylinders, 4½ inches; stroke, 4½ inches.

There is also a steam steering engine, made by the contractors, of vertical, double-cylinder type; diameter of cylinders, 4 inches; stroke, 4 inches.

In addition, the boat is provided with steam radiators.

The steam traps provided for the heating system are of the Kieley's Cantilever Expansion type. The design appears to be particularly well adapted for use on torpedo boats. The main steam separator drain traps are of the contractors' design, as well as that on dynamo-engine separator. They are made with ball floats.

Following is a recapitulation of weights of machinery:

	Tons.
I. Propelling machinery,	178.43
II. Water in above machinery (boilers 4 inches above highest heating surface),	14.16
III. Stores, tools, instruments and duplicate pieces,	8.30
IV. Miscellaneous machinery under Bureau of Steam Engineering,	3.76
Total weight at time of completion of machinery,	204.65

The weights were made up for the official trial as follows:

	Tons.
Propelling machinery, including necessary water, stores, tools and miscellaneous machinery under Bureau of Steam Engineering,	196.91
Hull and fittings,	175.00
Coal, ordnance, equipment and crew,	72.09
Total trial load,	444.00

All fittings on steam lines were made of manganese-bronze, with the exception of flanges, although only composition was required by the specifications.

TRIAL.

The *Stewart* left the contractors' dock, Morris Heights, New York City, at 7·10 A. M., October 20, 1902, for Newport, R. I., arriving there on the same day.

The crew on this run and on the subsequent trial runs was made up of men from the contractors' shops. Mr. Chas. L. Seabury, Vice-President of the contractors' firm, had immediate charge of the trials for the contractors.

The crew consisted of the following men:

For the Engineer's Force:

One master mechanic in charge.
Two licensed chief engineers (marine).
Two draughtsmen (recorders).
Eleven engineers and oilers.
One coppersmith.
One iron worker.
Two blower men.
Two machinists.
Two water tenders.
Eight firemen.
Two foremen for fire rooms (one superintending boiler maker and one leading man).
Eight coal passers.

The crew on deck consisted of one captain, one mate, one boatswain, three deck hands, five cooks and messmen.

There were five preliminary contractors' trials. Most of the trial crew had previous experience on torpedo-boat trials.

On October 22, 1902, the *Stewart* successfully completed the standardization trials on the measured trial course at Newport. The trials commenced at 1 P. M., and were completed at 2·31 P. M. The one-hour's endurance trial followed the next day, and was successfully completed at 10·48 A. M.

The trials were conducted by the Naval Board of Inspection and Survey, composed of Captains Charles J. Train and Charles R. Roelker, Naval Constructor J. J. Woodward and Commander Walter C. Cowles.

Captain Roelker, the engineer expert of the board, was assisted in taking engine data, etc., by Lieutenants W. C. Herbert and

Daniel S. Mahoney, U. S. N. Lieutenant Albert Moritz, U. S. N., the Inspector of Machinery at Gas Engine and Power Co., and the author of this article, was also present, on orders from Navy Department, to furnish information and render assistance to the trial board.

No indicator diagrams were taken during the trial.

The conditions of wind and sea were not very favorable for the endurance trial, as it was raining and there was quite a heavy swell. Several double runs were made for screw standardization, at the rates prescribed by the precept furnished the trial board. The beginning and the end of the measured mile were marked by an observer—one of the Naval Board.

TABLE I.—STANDARDIZATION TRIAL OF TORPEDO-BOAT DESTROYER *STEWART*, OCTOBER 22, 1902.

.....	First double run.		Second double run.		Third double run.		Fourth double run.	
Direction.....	S.	N.	S.	N.	S.	N.	S.	N.
Duration, mins. and secs....	2-39.5	2-40.2	2-26.9	2-30.0	2-04.0	2-12.0	1-57.8	2-04.9
Speed of vessel, knots.....	22.57	22.47	24.51	24	29.03	27.27	30.56	28.82
Mean speed during double run, knots.....	22.52		24.255		28.15		29.69	
Total revs. during each run:								
Port.....	633	675	639	688	647	694	648	697
Starboard.....	647	680	654	693	661	705	...	704
Mean revs. per minute during double run.....	247.27		270.15		317.2		...	
Mean apparent slip of screws per cent. (for one engine).	13.8		16.01		16.02		15.5	
Steam press. above atmosphere in engine room:								
Port, pounds.....	243	240	242	223	247	247	256	251
Starboard, pounds.....	242	239	241	230	247	244	260	250
Steam press. above atmosphere in H.P. valve chest:								
Port, pounds.....	125	125	160	170	225	225	254	250
Starboard, pounds.....	121	120	150	165	225	225	250	250
Steam press. above atmosphere in first receiver:								
Port, pounds.....	28	32	38	45	69	68	80	80
Starboard, pounds.....	29	27	37	41	67	66	81	77
Steam press. above atmosphere in second receiver:								
Port, pounds.....	— 1.0	0.0	3.0	5.0	11.0	11.0	15.6	15.7
Starboard, pounds.....	— 4.0	— 4.0	— 0.5	0.0	8.7	10.3	16.7	14.3
Vacuum, port.....	27.5	27.5	27.5	27.3	27.3	27.4	27.0	27.0
starboard.....	27.7	27.5	27.5	27.5	27.0	27.3	27.5	27.5
Air press., forw'd fire room..	1.0	1.0	1.0	1.5	2 3	2.0	5.3	6.2
after fire room...	0.0	0.0	.25	.50	2.14	1.96	6.6	6.3

HULL DATA CORRESPONDING TO OFFICIAL TRIAL CONDITIONS, OCTOBER 22, 1902.

Length between perpendiculars, feet	245
over all, feet and inches	250–6
Beam, extreme, feet and inches	23–6¾
at midship section on L.W.L., feet and inches	23– ½
Midship section (immersed), area, square feet	112.5
Draught at beginning of trial, forward, feet and inches	5–9½
aft, feet and inches	8–7
at end of trial, forward, feet and inches	5–6½
aft, feet and inches	8–6½
mean, for trial, forward, feet and inches	5–7⅞
aft, feet and inches	8–6¾
feet and inches	7–1 5/16
Displacement at load draught, tons	609.46
mean draught on trial, tons	444

FULL-POWER CONTRACT SPEED TRIAL U. S. TORPEDO-BOAT DESTROYER *STEWART*, OCTOBER 23, 1902.

Time, A. M.	Counter.	Revolutions per minute.	Steam pressure above atmosphere.				Vacuum, inches.	Air pressure.
			Steam pipe, engine room.	H.P. valve chest.	First receiver.	Second receiver.		
			STARBOARD ENGINE.					*
9·48	64,600	...	260	250	75	13	27.5	3.25
9·58	67,843	324.3	250	250	72	11.5	27.5	4.00
10·08	71,118	327.5	250	245	75	12	27.5	5.75
10·18	74,419	330.1	245	240	70	11	27.5	5.50
10·28	77,737	331.8	260	250	75	12	27.5	5.25
10·38	81,029	329.2	260	250	75	12	27.5	4.25
10·48	84,344	331.5	260	250	75	12	27.5	5.75
Mean..	19,744/60	329.07	255	248	73.7	11.9	27.5	4.82
			PORT ENGINE.					†
9·48	78,500	...	257	255	80	17.5	27.0	6.0
9·58	81,797	329.7	240	240	76	15.0	26.75	6.0
10·08	85,110	331.3	242	240	79	16.5	27.0	3.5
10·18	88,423	331.3	235	235	74	14.5	26.75	3.8
10·28	91,703	328.3	254	254	82	16.0	27.0	4.2
10·38	95,012	330.9	247	247	77	15.5	27.0	4.5
10·48	98,356	334.4	250	250	79	15.0	26.75	4.5
Mean..	19,856/60	330.93	246.4	246.0	78.1	15.7	26.90	4.64

* Forward fire room. † After fire room.

SOME TRIAL OBSERVATIONS.

The steam gauges in engine and fire rooms were tested before and after the trials, and the data given represents the corrected readings in accordance with these tests.

The safety valves were set to blow off at 265 pounds above the atmosphere, and were observed to lift at that pressure several times during progress of the trials.

The revolution counters of the engines were installed on deck operated by worm gear from the main shafts. They were provided with clutch couplings to throw them in or out of gear.

The fuel used during the trial was picked Pocahontas coal, of good quality. No record was kept of the amount consumed.

The machinery, both main and auxiliary, worked very satisfactorily during all the runs. The throttles of both engines were fully opened during the standardization runs as well as during the full-power speed trial. The vibration of the engines and pipes was very slight. No water was used except a small trickle on each eccentric and on the after main bearing.

"Reflex water gauges" (Klinger's patent) were used on the boilers during the trials. They proved extremely satisfactory and the height of water could be readily seen at all times.

The air pumps worked excellently without causing any anxiety whatever.

The fire-room blowers and engines, built by the Company, were extremely steady and free from vibrations at speeds ranging from 700 to 800 revolutions and while maintaining an air pressure in the fire rooms of about 6 inches.

The blower engines are of the double-cylinder type, diameter of cylinder, 5 inches; stroke, 5 inches, with cranks set opposite.

The trial displacement was 24 tons more than the designed trial displacement.

The vessel was docked on the 14th of October, eight days previous to the trial.

The standardization and endurance trials were completed without the slightest mishap, within a period of twenty-two hours, viz: 1 P. M. October 22, 1902, to 10·48 A. M. October 23, 1902.

As it was apparent that the required speed was not difficult to

attain, the contractors did not do their utmost to get the best speed.

A thorough inspection of the machinery after the trial showed it to be in excellent condition. The tubes of boilers showed no signs of distortion and their interior was free from grease. The condensers were tested to 25 pounds after the trial and found to be tight.

The *Stewart* was preliminarily accepted at Navy Yard, New York, on the 17th of November, 1902. Official mention was made of the very fine condition in which the Steam Engineering Department was found.

In conclusion, I have to thank Mr. Chas. L. Seabury and his assistants of the Gas Engine and Power Co. for valuable assistance and drawings furnished.

STEEL CASTINGS.

By Lieutenant Commander George S. Willits, U. S. N.

The steadily increasing use and importance of steel castings, the improvement in the methods of their manufacture and in the resulting product, and the lack of literature of a general character on this important topic should make an article touching on the matter of more than passing interest to the modern engineer.

There are books and papers without number on the subject of foundry practice, and on the theories of the processes involved therein, but they are so elementary on the one hand or so technical on the other as to make the middle ground seem great in extent and rather bare.

BUILDINGS AND THEIR USES.

The ideal steel-casting plant is one so arranged and equipped as to make the various processes involved in turning out a steel casting march along progressively from the beginning to the end with a minimum expenditure of labor, time and material, the appliances and machinery used being so grouped and located that the order for a casting and its accompanying blue print may enter at one end of the plant, the manufacture proceed continuously through, and the resulting finished object come out at the other end accepted and ready to be shipped to its destination.

A sketch of such a plant is shown in figure 1, indicating not so much a foundry building and its contents as the relative grouping of the principal apparatus used. This scheme calls for two parallel lines of runways or tracks for traveling cranes. With a design of building with a large central bay and a smaller bay or a lean-to on each side, the drying ovens must not occupy valuable central space but be placed against one of the side walls. Foundries intended to turn out special lines of steel castings are

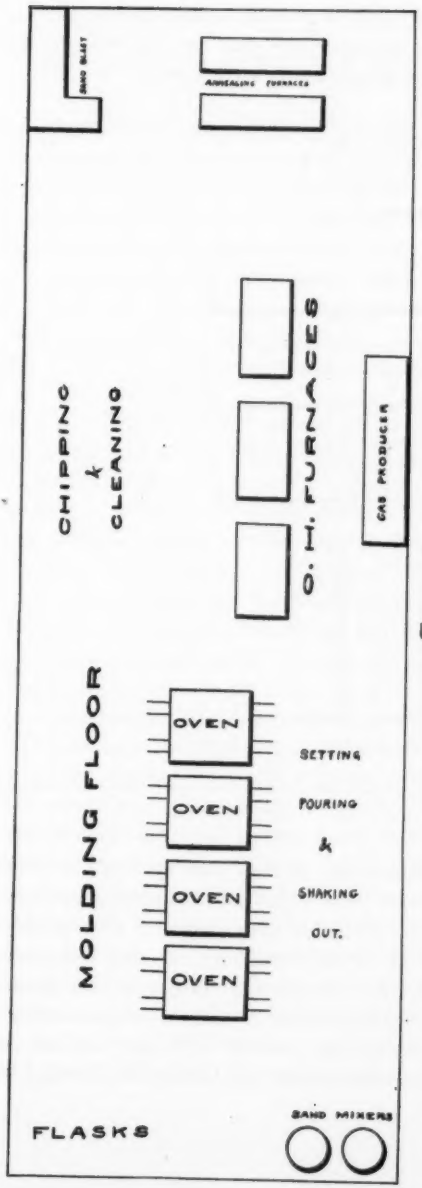

SAND BLAST
ANNEALING FURNACES
CHIPPING & CLEANING
O. I. FURNACES
GAS PRODUCER
MOLDING FLOOR
OVEN
OVEN
OVEN
OVEN
SETTING
POURING
&
SHAKING
OUT.
FLASKS
SAND MIXERS

Figure 1.

fitted with special labor-saving contrivances, such as traverse tables and molding machines, and have special practices evolved by the character of the work turned out.

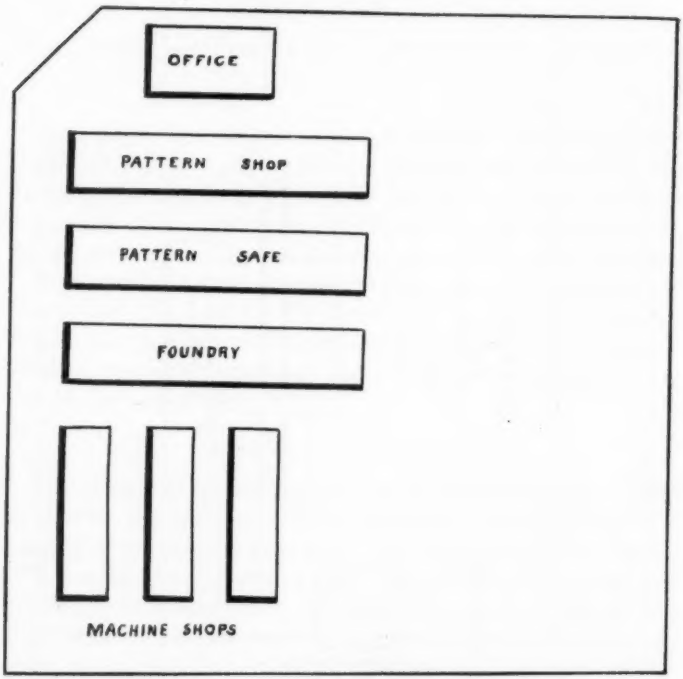


Figure 2.

Figure 2 shows the general arrangement of buildings of a concern out west that turns out machinery castings of steel in large quantities. Here the chief object is to provide liberally for future extension of the buildings to meet the demands of increasing business. The pattern shop, safe and foundry may be extended to the right, while the machine shops may be lengthened and increased in number. To give an idea of size and capacity in connection with this matter of plants, it may be well

to say here that it is estimated that in a building about eight hundred feet long and one hundred and forty wide, fully equipped, a monthly output of about two million pounds could be accomplished.

Besides the building for the foundry proper there are, as necessary parts of the plant, a pattern shop, an isolated pattern safe or pattern storage house, a machine shop or shops, a laboratory for making physical tests and chemical analyses, with an etching and micro-photography adjunct; a boiler house, electric-power house and a shipping warehouse; also a yard for storage of flasks, with sheds and bins for fuel, ore, pig iron, steel scrap, limestone, sand, fire and common brick, etc., and, last but not least, an office building with a room or rooms fitted and furnished for drafting purposes.

The roofs of the main buildings should be so constructed and glazed as to admit the maximum quantity of light, and means be provided for frequent and easy access to the glazed surfaces for cleaning away the dust and smoke deposits. The design of the roof should call for liberal ventilation, but means for excluding severe weather must not be lost sight of. The walls should be pierced at frequent intervals for windows and doorways of generous size. A very suitable shape for the cross section of this building is one which gives two parallel and equal bays over which electric traveling cranes should run, one or two large ones on higher rails and smaller ones below, the capacity ranging from five to possibly as high as fifty tons, if the weight of the work likely to be turned out warrants this maximum limit. Narrow and standard-gauge tracks should run the length of the bays, with external connections for bringing in raw materials and supplies and for carrying out the product. Cross tracks should be laid where most convenient to facilitate transference of work from one bay to the other. Electric arc lights should be liberally furnished to facilitate work by day when the daylight is insufficient from any cause, and for night work when such is required.

The processes to be carried on in these buildings and other parts of the plant are varied: Preparing drawings and blue prints, receiving and storing supplies, making patterns and core boxes,

mixing and preparing the molding sand, assembling the flasks and digging mold pits, making the molds and cores and drying them, producing the fuel gas, charging the open-hearth furnaces and making the steel, heating the ladles, tapping the furnaces, pouring the molten steel into the molds, cleaning, annealing, testing, machining, surface inspecting and stamping the castings, and, finally, shipping them.

MANUFACTURE OF THE STEEL.

The raw materials that usually enter into the making of steel castings are steel scrap, pig iron and iron ore. The scrap consists of the crop ends of plates, shapes and forgings and the borings and turnings from the machine shop. The bulk of the furnace charge is scrap, the proportion of pig being about one-fifth at the beginning of a run—that is, immediately after a furnace has been rebuilt—and increasing up to nearly three-tenths at the end of the run, when the furnace lining and brick work generally is getting so slagged and burnt out as to require renewal. These proportions are for acid steel, basic steel using larger quantities of pig. The amount of iron in the ore is a secondary consideration, the ore being used chiefly for its oxygen, which comes into play in oxidizing the metalloids carbon, silicon, sulphur, phosphorus. The proportion of ore required in a charge depends upon the character of the other ingredients, ordinarily in an acid furnace from one to two, or two and a half, per cent. would be used. There have been cases where scrap could not be procured, and the charge has been made up, of necessity, entirely of pig and ore, over three-fifths being pig. Hematite ore is the variety most used, and is obtained in large quantities in the Lake Superior region in this country and Canada; also much is imported from Cuba, Spain and elsewhere.

The exact constitution of the raw material is determined in the laboratory, and the exact proportions in the charge fixed according to the character of the steel wanted in each case. The amount of carbon combined with iron makes one difference between wrought iron and steel and between steel and cast iron. A second and equally important difference is the method of

manufacture and the resulting properties and character. Wrought iron is soft and fibrous, cast iron is hard, crystalline and brittle, steel comes in anywhere between.

Basic steel is used in making castings, but not so generally as the acid product. Cheaper raw materials can be used in making basic steel, and phosphorus, the element chiefly objected to, can be nearly eliminated. It is more expensive than acid steel, however, and fewer heats per run of furnace can be turned out. With acid steel the number of heats will reach nearly three for each twenty-four hours, depending upon the size of furnace and character and quantity of work.

OPEN-HEARTH FURNACES.

These raw materials are melted down in a reverberatory furnace with gaseous fuel distilled from special bituminous coals in gas producers. Under each end of the furnace is a pair of regenerators, one for air, one for gas, which communicate with the furnace on one side and on the other with flues leading to the sources of supply of gas and air and to the chimney. Reversing valves are located at the point where the flues meet, and about every twenty minutes, while the furnace is in operation, the valves are shifted and the currents of air and gas turned in the opposite direction. Each regenerator is nearly filled with fire brick built up in such an open checker-board manner that the air and gas find their way among and through them, absorbing heat from them on their way to the hearth, and, when spent, giving up heat to those in the opposite regenerators.

With this type of furnace a temperature of 4,000 degrees Fahrenheit can be attained, but as the supply of gas and air is at all times under control the temperature can be made whatsoever may be desired. If it were possible to introduce air into the open-hearth furnace under the bath in great abundance or superabundance, in some such fashion as in the Bessemer converter, the steel maker could dispense with the use of ore, as he would not need its oxygen; as it is, the heavy and thick layer of slag prevents the down-directed current of air from penetrating and mixing with the molten metal. The process in the furnace will be acid or basic according to the character of the furnace lining,

basic lining and additions being used in the one case, and an acid lining, such as ordinary fire brick and fire clay, in the other.

In the rolling or tilting furnace the hearth is contained in a cylinder which revolves axially through a considerable angle upon rollers, the advantages being the maintenance of the operation continuously, the ability to draw off as much or little of the bath as may be wanted at any time, protection to the bottom from the action of the corrosive slag by retaining some portion of the bath, and the consequent prevention of the damage and loss from run outs or leaks; opportunity to repair the lining at the slag line without interrupting the operation of the furnace, a clear tap at all times, and ability to draw off some of the slag whenever deemed advisable. The installation is expensive.

In the ordinary type of furnaces, as the period of time required to make the melt draws to a close small dipperfuls of the steel are obtained and poured into an open metal mold, and these bars when quickly cooled are broken in two and the character of the bath approximately judged by the appearance and color of the fractures, and more accurately, and a little later, by short-method analyses of drillings from the last of these bars. The bath then, being found right, or made so, is ready to be recarburized with calculated amounts of ferro-silicon and ferro-manganese, which effect the final reduction of the oxides of iron and raise the percentages of carbon, manganese and silicon to the points necessary to give the required physical properties. The metal is then tapped into a large ladle and carried to the molding floor and run into the molds. A small portion of the fluid metal is poured out of this ladle and analyzed, giving the "ladle analysis," as it is termed. Two sets of analyses, twenty in each set, were taken as they stood on certain records and averages worked out, the results as found are given below in percentages.

Carbon.	Silicon.	Manganese.	Sulphur.	Phosphorus.
.332	.339	.696	.0414	.049
.282	.294	.647	.042	.0508

The first set is from melts for castings which had to furnish test specimens able to meet the specifications of the U. S. Naval

Bureau of Steam Engineering, which called for an ultimate tensile strength of 70,000 pounds per square inch, an elongation of at least 10 per cent. in eight inches, and a reduction in area at the point of fracture of the test specimens of at least 20 per cent. The second line of determinations were from castings whose test specimens had to show at least 60,000 pounds tensile strength, 15 per cent. elongation, and a reduction of 20 per cent. These same specifications fix a top limit of .06 of one per cent. for phosphorus in steel castings, as any greater quantity of this element is considered injurious, producing "cold shortness." Phosphorus should be lower than .06 in ladle analysis, as it will run higher in the later determinations. Sulphur is also kept at a low percentage, although the amount is not specified, as any considerable quantity of it would cause the metal to fail to meet the physical requirements. In steel forgings sulphur would interfere with working the metal, producing "hot shortness," and the Government names a maximum limit of .04 per cent. The other three constituents given in the above analyses more or less determine the behavior of the metal in the testing machine.

If, following a common practice, we should say that a *hundred points* of any one of these elements is equal to one per cent. or 1.00, we can discuss this phase of the subject more conveniently. With a mix containing ten points of carbon, fifty-five manganese and eighteen silicon, or 10 C, and Mn and Si normal, we will have 55,000 pounds tensile strength in our metal, ten more points of C will make it 65,000 pounds, and thirty C will make it 75,000, or 1000 for each additional point of C. Putting this in tabular form we have:

C.	Mn.	Si.	Tensile strength.
10	Normal	Normal	55,000
20	Normal	Normal	65,000
30	Normal	Normal	75,000

Adding ten points of Mn above the normal adds 3,000 pounds to the tensile strength, so that, wanting a steel of 80,000 pounds tensile, we can provide a mixture of

C — 31 = 10 + 21, giving	55,000 + 21,000 =	76,000
M — 70 = 55 + 15, giving	4,500 =	4,500
Si — 18		
		80,500

Manganese in steel making facilitates the combination of carbon with iron, increases fluidity, prevents ebullition during solidification, tends to counteract evils produced by presence of copper, silicon and phosphorus, increases the tensile strength, diminishes fusibility. Silicon increases fusibility and fluidity of steel, lessens formation of blow holes, increases tensile strength slightly, renders steel brittle, prevents red shortness; the possession of these last three properties is disputed by many metallurgists. Phosphorus causes the steel to be thoroughly untrustworthy, especially when subjected to sudden shocks or vibrations. It tends to segregate, and the proportions in different parts of a casting will vary considerably.

MOLDING AND CASTING.

The pattern shop, equipped with the usual wood-working machinery and appliances, handles clear, white pine almost exclusively for turning out patterns; sometimes for small patterns to be much used, clear, mellow cherry wood is employed. When the patterns are made in parts, these should be doweled together accurately so as to mate exactly while the mold is being made, and if the pattern is to be handled frequently, the dowel pins should be of metal and their sockets be made with plates, otherwise repeated rappings to loosen them from the sand will wear the pins and sockets and cause the parts of the pattern to match badly. The cross section of parts to be drawn from the sand should show a slight taper. An allowance for shrinkage of three-sixteenths to sometimes as little as one-eighth of an inch to the foot is made by the pattern maker in making a pattern for a steel casting. Figure 3 shows a ship's stem of cast steel, and the differing amounts of shrinkage and their locations are indicated. As a rule patterns are coated with orange-colored shellac and the core prints painted black.

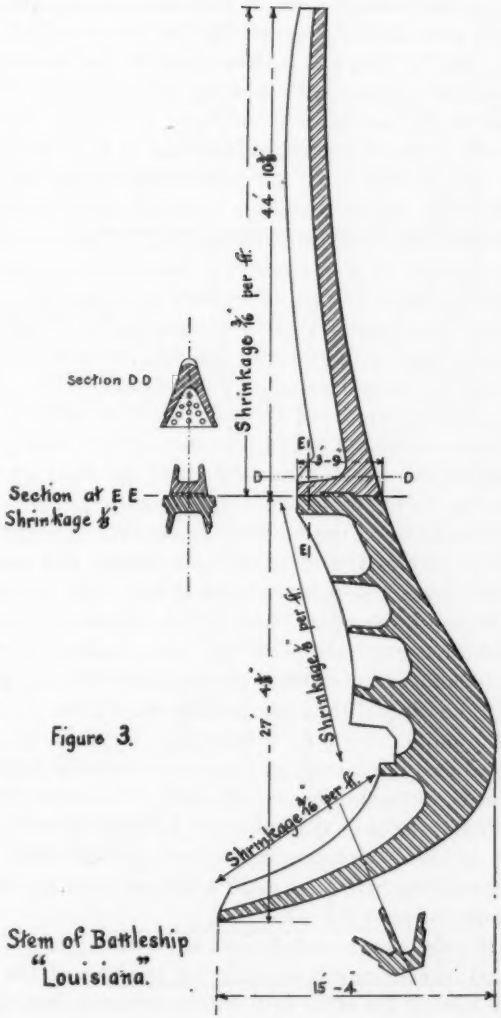


Figure 3.

Stem of Battleship "Louisiana."

In the flask yard we should find a good lot of cast-steel flasks and plates of the smaller sizes needed and a varied assortment of sides and ends for building up large flasks as required. After the molder has his flask and pattern ready for use he begins filling in around the pattern with molding sand, ramming it harder than would be the case for iron castings; he uses a good, sharp bar sand with just enough binding material to hold the particles together. Beach sand is not good, as it may contain salt, which absorbs moisture readily; besides it is not sharp enough, the corners and angles being worn off by long continued attrition due to its location on a sea beach. The sand is prepared in a mixer, which consists of two heavy steel-tired cast-iron chasers revolving on a horizontal axis in a revolving pan; the sand is mixed, if necessary, with molasses and flour, a tank and bin for which are conveniently located near the mixers. The molasses bonds the grains of sand, and when the mold is baked its evaporated moisture leaves the sand open and porous, aiding thus in venting the mold. Back of the sand which lies next the pattern the molder fills in the flask with cinder to allow for venting and yielding of mold when the metal is solidifying and shrinking; he also freely pierces the mold with his venting rod and opens vents to the cores through the core prints. He works in, as parts of the mold, spaces for coupons for furnishing test specimens, webs for strengthening flat surfaces, brackets to reinforce junctions of surfaces and parts of varying thickness, and provides runners for pouring, with gates leading from them to different parts of the mold. To give a ferrostatic head to the molten metal and to feed the casting as it cools and shrinks he provides sinking heads, or feeding heads, or risers, as they are variously called. The surfaces of the mold are finished off with a wash composed of silica, molasses and water, applied deftly with a swab; between the parts of a mold a parting sand is used, consisting simply of pure dry silica.

In figure 4 the runner is indicated at R. With large castings having a tall runner care is required on the part of the molder to provide against the effect of the drop of the molten metal on the bottom of the runner, the mold might be broken here more

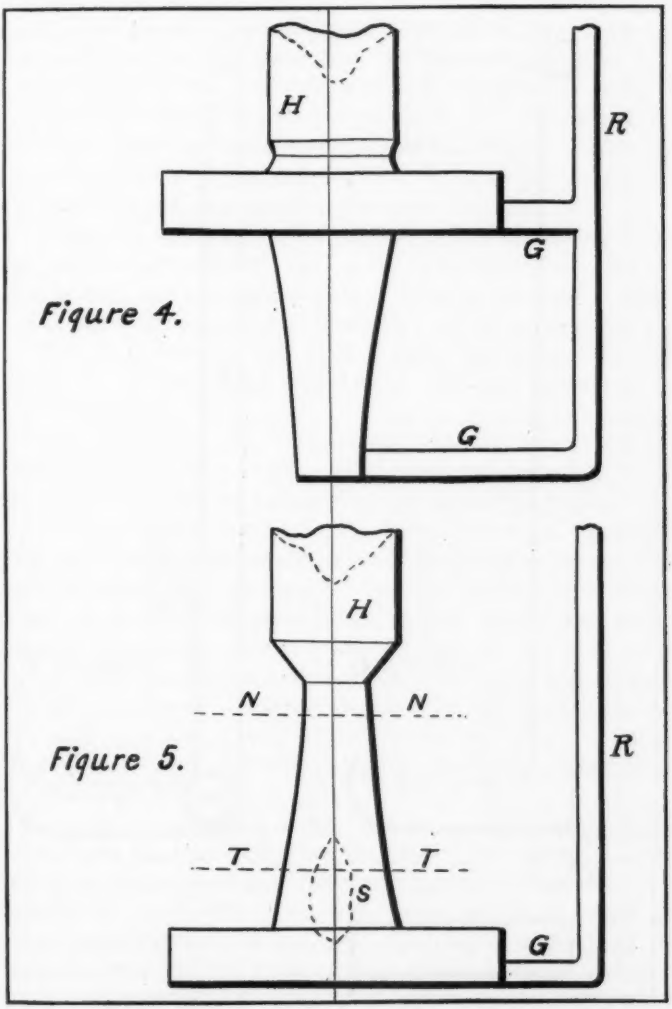


Figure 4.

Figure 5.

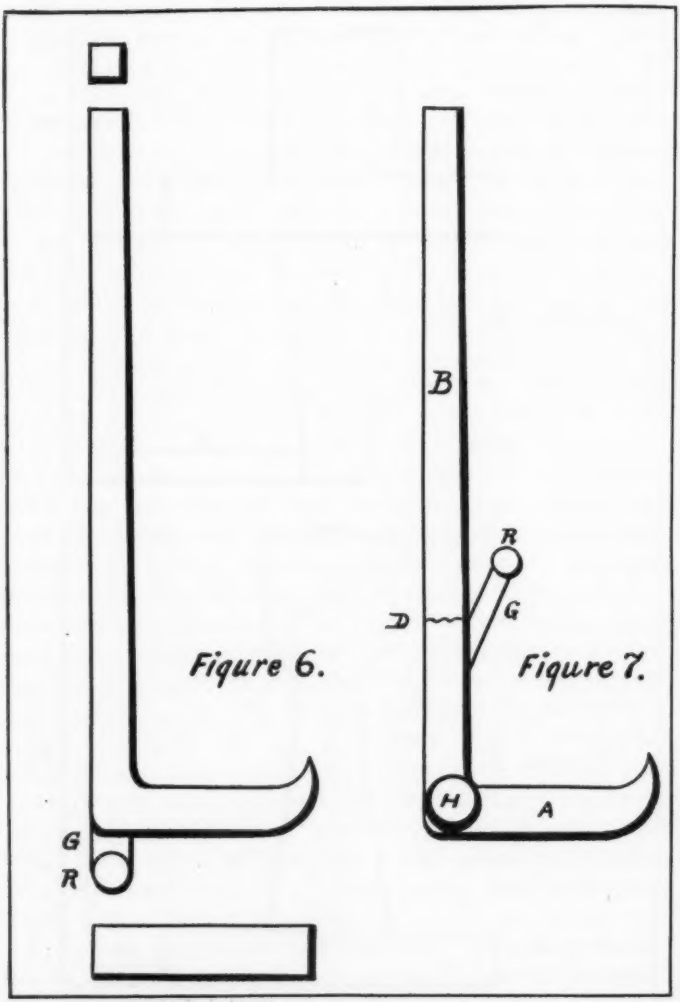


Figure 6.

Figure 7.

or less seriously. In figures 4 and 5 G and G indicate the gates and H the risers. In figure 5 the molder has made an unscientific job of his work; he will have a shrinkage cavity at S, because the metal will not feed down from the head and fill out at T T a greater cross section than exists at N N, the smallest part. In figure 7 the mold was gated improperly and the casting was cracked across at D, the acute angle at junction of gate with mold giving a starting point for a crack which the resistance of the mold to the shrinking was thus able to cause.

When the method of gating shown in figure 6 was employed sound castings resulted; the runner R in this figure answered for a head, and the neck or gate G being of same cross section as the casting the mold was freely fed. If the parts of the flask and mold fit badly or they yield under the pressure of the fluid steel, fins will be formed by the metal running out laterally into thin, flat sheets.

After the molds are made and finished they are placed on a buggy and run into the oven to be dried; the cores also, if they are large or numerous; otherwise they are placed in recesses or on shelves in the oven by hand. When these are thoroughly baked they are run out at the opposite end of the oven, assembled and set up squarely on the floor near the melting furnaces, and head boxes where required fitted over the tops of the runners. Wood and coal are used to heat the ovens, but the most recent practice is to use producer gas. While these operations are going on and the charge is melting down in the open-hearth furnace, the large ladles are swung by their trunnions, bottom up, in the drying frame and their linings thoroughly dried and heated by means of oil burners.

The next operation is to tap the furnace and run the molten metal into the ladle. If when the ladle is full the metal is violently boiling, a small quantity of pure aluminum is thrown in to subdue the ebullition. The ladle is now carried by one of the big traveling cranes to and over the waiting molds, and the stopper lifted and the metal allowed to run from the bottom of the ladle into the molds one after another. Off to one side of the foundry a small number of crucible furnaces have been in opera-

tion meanwhile, melting down in clay crucibles, about ninety pounds each, the same steel, and these crucibles are carried to the molds to make good small deficiencies in the runners and risers due to cooling and shrinkage, this while the mass of the metal is still fluid. The shrinkage of the steel, which is 5.56 per cent., must now be accommodated by the yielding of the mold, and at the same time any steam and gases generated or escaping from the metal must find vent through the mass of the sand and cinder.

CLEANING AND TESTING.

After a time, depending upon the size and weight of the castings, the flasks are knocked apart and the casting shaken out and the work of cleaning begins; a heat or individual number, or both, are then stamped on castings and coupons, and the fins, gates, runners, webs and brackets are hammered or chipped off; some of the risers are knocked off with the pear-shaped drop, large ones being partially sawed or drilled through at their base before the drop is used. The sand-blast apparatus is used to clean burnt sand from a casting and to give a sort of finish to the surface. Small castings are often cleaned in the rumbler or tumbling barrel, where the mutual battering and rubbing soon produce the desired effect, but to the detriment of sharp edges and corners. Upon completion of the cleaning processes the castings requiring annealing are placed in annealing furnaces, where they are gradually and uniformly heated up to temperatures depending upon the composition of the metal and varying between 1,200 and 1,600 degrees Fahrenheit, kept soaking at the maximum temperature for a time determined by their size, and then allowed gradually to cool without exposure to the air. When cold the coupons are detached and the necessary test specimens cut from them and machined accurately to required size. These specimens are then broken or bent in an approved testing machine according to the specifications prescribed. The latest specifications of the Bureau of Steam Engineering are here given in full:

(1.) The physical and chemical characteristics of steel castings are to be in accordance with the following table:

Class.	Material.	Treatment.	Minimum tensile strength, lbs. per sq. in.	Minimum elastic limit, lbs. per sq. in.	Minimum elongation, p. ct. in two inches.	Minimum reduction of area, p. ct.	Maximum.—P.	Cold bend about an inner diameter of one inch.
Class A....	Any approved process.	Annealed..	80,000	35,000	15	20	.06	Through 90°
B.....	Any approved process.	Annealed...	65,000	30,000	18	25	.06	Through 120°
C*...	Any approved process.	.....	...	...	...	...	...	.....

*Class C castings will ordinarily be subject to surface inspection only at the building yard. They will not be tested unless there are reasons to doubt that they are of a quality suitable for the purpose for which they are intended. Tests, if required, shall be made at the expense of the contractor, and may be made at the building yard. The inspector will select a sufficient number of the castings and have them crushed, bent or broken, and note their behavior and the appearance of the fracture.

(2.) *Kind of material.*—Steel for castings may be made by the crucible, open-hearth, Bessemer, Tropenas or any other process approved by the Bureau of Steam Engineering. The material must be of uniform quality throughout. In case of doubt on this point, the inspector will have drillings for complete analysis, taken from the surface and from the center of the thickest parts. In all cases analyses will be made for phosphorus, and no casting shall contain more than six one-hundredths of 1 per cent.

(3.) *Treatment.*—All castings, except those of Class C, shall be annealed, unless otherwise directed. If castings are subjected to any special treatment, the inspector will make such additional tests as he may deem necessary to see that the treatment has left the material of uniform character throughout. In case the results obtained by the first tests do not conform to the specifications, the manufacturer may re-treat the castings and submit additional pieces for test.

(4.) *Surface and other defects.*—All castings shall be thoroughly cleaned before they are presented for inspection. They shall be sound, free from brittleness, injurious roughness, sponginess, pitting, porosity, shrinkage and other cracks, cavities, foreign substance, and all other injurious defects. Particular search shall be made at the points where the heads or risers join the castings, as unsoundness at such points is likely to extend into the castings.

(5.) *Test pieces.*—Sound test pieces shall be taken in sufficient number to thoroughly exhibit the character of the metal in the entire piece from each of the following castings, viz: Shaft struts or brackets, main cylinder or valve-chest liners, main pistons and followers, eccentric, reversing and rock shaft arms, crossheads, bedplates, columns of main engines and main air pumps, shaft couplings, and all large castings weighing over 200 pounds. All other castings may be tested by lots, as follows: A lot shall consist of all castings from the same heat, annealed in the same furnace charge. From each lot two or more tensile and one or more bending-test pieces shall be taken, and the lot passed or rejected on the results shown by the tests. The test pieces may, at the discretion of the inspector, be cut either from coupons to be molded and attached to some portion of the casting, or else from sinking heads, in cases where such heads of sufficient size are employed. Coupons are to be attached so as not to interfere with the successful making of the casting, but at the same time to show the quality of the material. In the case of castings tested by lots, and if the manufacturer so desires, the test pieces may be taken from the body of a casting selected by the inspector from the lot. In no case shall the coupons be detached from their castings before they are stamped by the inspector. In special cases where the attachment of a coupon would be liable to injure the casting, the coupon may be cast with small runners to the gate, or separately in the same flask, so that they may be easily identified when the casting is knocked out of the sand. In all such cases the sanction of the inspector must first be obtained.

(6.) *Percussion test.*—Large castings shall be suspended and hammered all over with a hammer weighing not less than $7\frac{1}{2}$ pounds. No cracks, flaws, defects or weakness shall appear after such treatment.

DEFECTS.

Blowholes form, generally, in the mass of the casting just below the surface, and are more or less regular in size and relative location. As the fluid mass cools tiny bubbles of gas are squeezed out by the shrinking and solidification of the metal in which they have been held in solution, and these gather into tubular shape

perpendicular to the cooling surface. The office of silicon is to increase or prolong fluidity and thus give the gases a chance to get to the surface and escape, or to float toward the top into the risers, where they become harmless. The gases in these bubbles have been found to be hydrogen, nitrogen and carbonic oxide.

If a mold be insufficiently dried, or if allowed to stand long enough after drying to absorb atmospheric moisture, it may generate steam when it is poured, and the steam, going in the direction of least resistance, will enter the fluid metal and produce a general state of *porosity*. If this dampness is only local, this condition will not be general, and the casting will be *spongy* at the points where the mold was damp. Blowholes throughout the mass of the casting will put it in this porous condition.

If the mold is rammed so hard as not to yield readily to the shrinking of the casting, the latter will tear apart at the weakest or thinnest places, or where surfaces change direction, producing *shrinkage cracks*. Such parts of a casting should be protected against this possible damage by brackets and webs, which will be removed during the cleaning processes.

Scabs may be produced by injuries to the surface of the mold caused by its walls yielding on account of irregular ramming or by the washing or eddying of the fluid metal.

One theory to account for *pitting* is that pebbles may be in the sand at surface of mold, and the water of crystallization thereof, being converted into steam by the heat of fluid steel, intrudes in bubble form into the surface of the metal.

A mass of sand and cinder may be torn away from some part of a mold or core and become embedded in the casting, or some other *foreign* substance may be swept into the mold with the current of molten metal. Such an undesirable acquisition will injure the casting, possibly ruin it.

Brittleness in a casting may be produced by excess of phosphorus. This element tends greatly to segregate, and some part of a casting when subjected to strain in service may break from being brittle because a quantity of phosphorus greater than the limit allowed may be present there. Or the metal in a casting

Figure 9

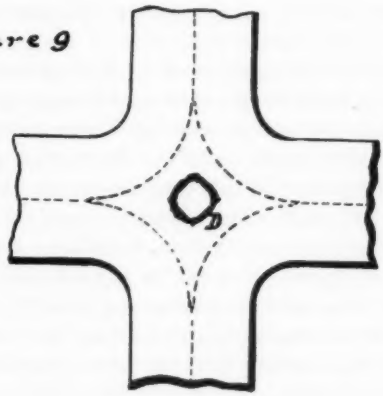
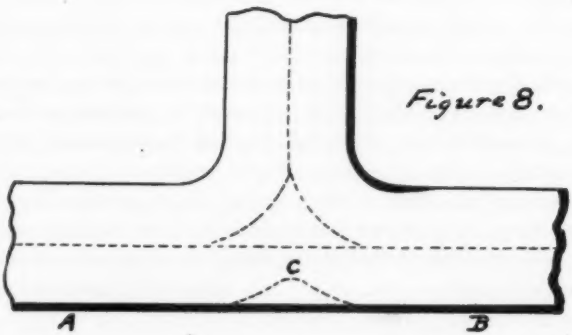


Figure 8.



may be brittle on account of crystallization produced by slow cooling.

Cavities occur in the heavy parts of a casting on account of faulty design or faulty molding. Figure 5 shows a cavity of this latter kind, and figures 8 and 9 illustrate the reason for the occurrence of cavities due to the design. At the junction of the two sections in figure 8 a triangular space is enclosed by the central planes which may contain a pipe or shrinkage cavity, because radiation of heat and consequent solidification cannot proceed in both directions at a uniform rate at this point, hence the metal remaining fluid longer here will feed the adjoining portion and so create a cavity. A riser at this point would remedy the evil, but cases will occur where such cannot be attached, then if possible the draughtsman should curve the line A B as far in as C so as to give more uniform section; in figure 9, adjoining, the section can possibly be cored out, as shown at D, if a riser cannot be used, and surfaces for radiation thus presented providing for cooling and shrinking on both sides of the central planes.

USES OF STEEL CASTINGS.

Steel castings are used for cylinder and valve-chest covers, for pistons, crosshead guides and slippers, bearing caps and shoes, eccentric sheaves and straps, rocker arms, thrust-bearing boxes and collars, bed plates and housings and other parts of main and auxiliary machinery; for boiler headers, manifolds, drum ends, dry pipes, manhole and handhole doors and other parts of boilers; anchors, anchor davits, hawse pipes, chocks, mooring and towing bitts, stems, stern posts, stern tubes, shaft brackets, manhole covers and other parts of ships' hulls; gun mounts, parts of dynamos and motors. Their use in ship construction and aboard ship is thus seen to be a large and important matter.

The cast-steel girders for the 16-inch Army gun carriage, the gun now being tested at the Sandy Hook proving grounds, measure each 33 feet by 17 feet by 5 feet, and will weigh about 100,000 pounds apiece; the carriage presents problems in transportation from the foundry to the arsenal at Watervliet on account of size and weight. A large casting turned out in

the eastern part of Pennsylvania for a hydraulic forging press to be set up in the western part of the same State required about 320,000 pounds of metal from six open-hearth furnaces to pour it.

CIRE PERDU PROCESS.

Some five hundred years ago, more or less, a method of casting bronze statuary in which wax played a chief part was evolved and practiced. A mass of clay was built up into a shape roughly resembling the desired figure, and this was coated heavily with the wax preparation. This wax was then cut and carved into the finished shape, and, in its turn, covered with a heavy layer of clay. By sufficiently heating the mass the wax was melted out, leaving a perfect mold and core, and the molten bronze was then run into it and the desired statue thus produced. Today there is a patented process in use for turning out a large number of steel castings of the same size and shape which makes use of this idea. A master mold of cast iron is made, and a number of patterns are cast in this of an alloy fusible at low temperature, such as a mixture of antimony and bismuth. The damp molding sand is thrown at and around these alloy patterns by pneumatic apparatus, and the molds, thus quickly and cheaply made, are then dried in the usual way. The heat of the drying ovens melts the patterns, and the fluid alloy runs out at the bottom of the mold and is caught to be used again. The bottom of the mold being closed, fluid steel is poured in, and when the castings are shaken out very little cleaning is required to present them ready for service or for the machine shop.

ARE STEEL CASTINGS RELIABLE?

A forged or rolled object is worked down from a billet which previously was hammered or pressed down from an ingot or part of an ingot, and during these stages of manufacture the metal is more or less thoroughly squeezed and pressed and caused to flow upon itself in various directions, and all parts, inside and out, receive some heat and power treatment, so that the impression grows in the minds of those who manipulate the forgings and of those who witness the manipulation that the accepted objects

are free from weakening defects; the assurance of their trustworthiness is positive.

In the case of castings no such certainty or confidence is created. A steel casting may come out of the final cleaning process a thing of beauty, the physical and chemical tests may gladden the heart, the required machining may show up no flaws, yet the fear will not down that below its surface somewhere a treacherous cavity or other weakness may some day get in its deadly work, a day when most dependence is necessarily placed upon the casting, when most damage may result from its failure to do its duty. However, the industry is steadily improving; all things human, especially all things American, are marching forward, and in time this fear will disappear, and eventually as much reliance be placed in a steel casting as in a hammered, pressed, rolled or drawn object, but the question may now be asked, Is that time in sight?

THE NEW BRITISH ADMIRALTY SCHEME OF TRAINING NAVAL OFFICERS.

If the statement of Captain Mahan is true that naval victories are more likely to be achieved by good men in command of poor ships than by poor men in command of good ships, then everything relating to the training of the personnel of the British Service must be of commanding interest to naval students throughout the world.

As mistress of the seas, England has every reason to maintain her present dominion as regards sea power, and therefore the comprehensive and new scheme of entry, training and employment of officers and men of the Royal Navy is direct evidence that her experts believe that the military conditions of today warrant new methods as regards recruiting both the commissioned and enlisted force of the Navy of Great Britain.

The policy of the British Admiralty in amalgamating the duties of the Executive, Engineer and Marine officers, is either a direct advance in naval strength or it is an error of judgment that may even imperil the existence of the empire. The projected changes, however, show such exceeding care and thoughtful reflection that a comprehensive knowledge of its scope and purpose can only be secured by studying the memorandum in its entirety.

The more carefully the various sections of the measure are considered the more impressed one is with the fact that every feature of the scheme is the project of extended study and experience, and that the Admiralty takes the step in the confident expectation that the personnel of the British Navy will remain, as it has in the past, the equal, if not the superior, of that of any rival service.—[THE EDITOR.]

The Memorandum of the Earl of Selborne, as First Lord of the Admiralty, dealing with the entry, training and employment

of officers and men of the Royal Navy and of the Royal Marines is exceedingly clear and explicit, and there is no hesitancy to sacrifice tradition for efficiency. It reads as follows:

"The Navy has reached a critical period in its development—a development which, steady and comparatively slow for the greater part of the last century, has now for fifteen years proceeded with startling rapidity. After the great war, from 1815 onwards, there ensued a period of readjustment and retrenchment; the half-pay list embraced the majority of the officers of the Navy; comparatively few ships were in commission; it was necessarily not a period of innovation or of new ideas. The application of steam to ships of war as a source of motive power was the first sign that the old order was beginning to change. At first admitted grudgingly as an occasional auxiliary to the sails, then acknowledged as an equal partner, then winning for itself supremacy, today the steam engine has no rival, and sails have forever disappeared from the equipment of fighting ships."

STEAM AND THE SHIP.

"Gradual as was the revolution in respect of steam, so were the changes gradual in respect of the type of ship, her armor and her guns. The wooden *Victory*, with her sail power and her one hundred guns, eventually became transformed into the iron *Inflexible*, with her oval-tank boilers and her four 80-ton guns, but the process had been a slow one. The Navy had then been brought to the verge of a period in which vast improvements were about to take place in the battleship herself and in all the material which she contained. Cylindrical or locomotive boilers at low pressures were to give place to water-tube boilers at 300 pounds pressure; the strength and power of the engines was to receive marvellous development; numberless auxiliary engines were to replace manual labor or to fulfill functions unknown before among naval requirements; muzzle-loading were to give place to breech-loading, and they in their turn to quick-firing guns; brown powders, with much smoke and low velocities, were to be replaced by smokeless powders giving an ever-increasing velocity; the storm of shot and shell capable of being poured

into or from a ship was to become ever more rapid and ever more murderous; to meet these conditions the whole fabric of the ship was to change, and Krupp or Harveyized steel to be substituted for compound armor, as compound armor had in its turn been substituted for iron; and finally, the ship herself, whose form and lines had during the transition period been the subject of wild experiment, was to regain a settled type in the *Majestic* class.

"By a strange decree of fate the climax of this revolution in the material of the Navy has synchronized with its recent extraordinary development of strength in ships and of strength in men. It is difficult to measure the change which has taken place in the last fifteen years. In that short period the officers and men of the Navy and Marines have increased from about sixty thousand to over one hundred and twenty thousand. There are several foreign Navies more powerful to-day than the British Navy was fifteen years ago, and yet the relative standard has been maintained. Of the ships which formed the effective fighting ships of the Navy fifteen years ago but few remain on the effective list now. The country can judge for itself what years of strenuous labor these have been for the Admiralty, years in which every task fulfilled was forgotten in the anxious effort to fulfill tasks which had yet to be done."

The Man of Many Parts.

"Throughout this period the Board never lost sight of the most important question of all those which confronted them, the education and training of the officers and men of the Navy, and the adaptation of that education and training to the new conditions under which the Navy has to work. Last year it was decided that the time had come formally to announce that training in masts and yards had disappeared never to return, and the growing importance of a fuller knowledge of engineering was emphasized by the order that in the future gunnery and torpedo lieutenants were to be held responsible for the care of the mountings and machinery of the weapons over which they have charge. In the old days it sufficed if a naval officer were a seaman. Now

he must be a seaman, a gunner, a soldier, an engineer and a man of science as well. It is not only that machinery driven by electric, hydraulic or steam power is every year becoming more complicated in character and multiplying in form, and that therefore a more extensive education in applied science is necessary for specialized officers, but in various ways the need for a more general scientific training has become apparent. In dealing with this question the Board have been always conscious of the supreme importance of preserving to the naval officer his unmistakable naval character.

"This character is developed from the early training in responsibility, the powers of self-reliance thereby engendered, and the essential unity of the Service. Notwithstanding the fact that during the transition period the system of naval education has been the subject of much criticism, the character of the naval officer has remained unimpaired, and character is of more value than knowledge. Now, however, as always, the highest type of naval officer is that wherein great professional knowledge is added to force of character. The danger within the Navy itself is lest insufficient importance should be attached to the results of study and lest the value of what is called the practical character should be placed higher than it deserves. It is true that no student will ever become a victorious leader unless he is also a practical seaman and has the power of influencing men; but it is also true that no seaman, however practical, will be fit to rise beyond a certain rank unless he has thought out the problems of his calling as a student, and has omitted no opportunity of acquiring the knowledge that makes up the science of his profession. The officers of the Navy have never had cast on them a greater responsibility than at present, or one more difficult to fulfill. Their task will be impossible unless the Navy is kept abreast of the scientific, intellectual and physical progress of the age, and it is they themselves who must keep it there."

The Strength of Unity.

"The strength which its unity gives to the Service can hardly be over-estimated, yet in respect of this very matter a strange-

ly anomalous condition of affairs exists. The executive, the engineer, and the Marine officers are all necessary for the efficiency of the fleet; they all have to serve side by side throughout their career; their unity of sentiment is essential to the welfare of the Navy; yet they all enter the Service under different regulations, and they have nothing in common in their early training. The result is that the executive officer, unless he is a gunnery or torpedo specialist, has been taught but a limited amount of engineering, though the ship on which he serves is one huge box of engines; that the engineer officer has never had any training in executive duties; that from lack of early sea training the Marine officer is compelled, sorely against his will, to remain comparatively idle on board ship when everyone else is full of work; and that the spirit of unity has not yet been carried to its full development.

"The Board of Admiralty have studied this question of the education and training of naval and Marine officers with prolonged and assiduous care, and they have determined on changes which they are convinced are adapted to the changed conditions of the time and will increase the efficiency and solidarity of the Service.

"These changes are far-reaching, and in some respects sweeping, but the scheme which necessitates them is framed in pursuance of a definite policy, is planned on clear lines, is designed to deal with the problem as a whole, and is throughout conceived in a spirit of veneration for all that is best and highest in the traditions of the Service."

The New Scheme.

The memorandum proceeds to give details of the new scheme:

"It has been decided that henceforth—

"1. All officers for the executive and engineer branches of the Navy and for the Royal Marines shall enter the Service as naval cadets under exactly the same conditions between the ages of twelve and thirteen;

"2. That these cadets shall all be trained on exactly the same

system until they shall have passed for the rank of sub-lieutenant between the ages of nineteen and twenty;

"3. That at about the age of twenty these sub-lieutenants shall be distributed between the three branches of the Service which are essential to the fighting efficiency of the fleet—the executive, the engineer, and the Marine.

"The result aimed at is to a certain point community of knowledge and lifelong community of sentiment. The only machinery which can produce this result is early companionship and community of instruction. These opportunities will be secured by a policy of—

"One system of supply.
"One system of entry.
"One system of training."

Training Up To Twenty.

Details are then given of the entry of cadets and training of cadets, midshipmen and sub-lieutenants up to the age of about twenty:

"I shall not attempt to give more than an outline of the scheme. Every detail connected with the education of these young officers will be carefully thought out and considered, and the best authorities, naval and civil, will be consulted by the Board of Admiralty.

"In the first place, I will explain why it has been decided to revert to the early age of twelve to thirteen for entry as a cadet. It is considered that entry at this early age is necessary if the cadets are by the age of twenty to receive that increased professional education which is required to qualify them to become commissioned officers; and it is not considered that it would be compatible with the welfare of the Service if they were to become commissioned officers at any materially later age. In addition to this fact the present scheme must be looked at and judged as a long and carefully thought-out whole. The complete development of the unity of the Navy is the great object which the Board have in view, and for this unity the early homogeneous training is essential. Moreover, the age of twelve to thirteen not only

corresponds to that at which the history of the Navy shows that boys have been most successfully molded to sea character, but also it corresponds to the age at which boys leave private schools, and, therefore, to a natural period in the system of education which obtains in this country.

"When the age of entry of cadets was raised to that at which it at present stands, owing to the necessity of shortening the period of training at the Royal Naval College so as to overtake the arrears in the supply of lieutenants to the increased fleet, it was hoped by the Board that the future cadets would come from the public schools. This hope has been only imperfectly realized. The majority of public schools have made no special effort to train boys for the Navy, nor can I consider this wonderful. Nevertheless, it would be ungracious and unjust to omit this opportunity of expressing the cordial acknowledgments of the Board of Admiralty to those schools which have made a special and successful effort to train boys for competition for the Navy. I greatly regret the disappointment that will be caused to them by the change of system, but in the opinion of the Board the interests of the Service require the change, and the Board of Admiralty would not be faithful to their duty if they allowed any consideration to outweigh what they are convinced is for the good of the Service."

THE ROYAL NAVAL COLLEGE.

"The entrance examination for the Royal Naval College, commonly known as the *Britannia* examination, will be of an elementary kind, and confined to those subjects in which a carefully educated boy has usually been instructed up to the age of thirteen. No change will be made in the present system of entering boys for the competition, but the medical evidence is conclusive that at this early age the examination must not be severe, and, indeed, that no examination of boys at this age or at the later age now obtaining can be considered an accurate test of what their comparative faculties will be when they have attained manhood. It consequently follows that during their period of training at the Royal Naval College cadets who fail to

attain a minimum standard or to show promise of sufficient development of intellect must be requested to withdraw.

"Cadets will remain under instruction at the Royal Naval College for four years before going to sea, and they will all receive similar instruction, which will comprise an extension of the *Britannia* course, including elementary instruction in physics and marine engineering, with the use of tools and machines in connection therewith. The object of this course will be to give them a good grounding in the subjects necessary to their profession, and at the same time such a general education as will enable them to grasp the theory of their future subjects of study, whichever branch they may eventually join."

CADETS GO TO SEA.

"At the end of this period the cadets will go to sea and become midshipmen (*Britannia* time counting, as at present). Special attention will then be paid to their instruction in mechanics and the other applied sciences, and to marine engineering. The instruction of the midshipmen in seamanship will be given, as at present, by an executive officer deputed by the captain; otherwise it will, under the general responsibility of the captain, be supervised by the engineer, gunnery, marine, navigating and torpedo lieutenants of their respective ships. They will be examined annually as to their progress in seamanship, navigation and pilotage, gunnery, torpedo work and engineering, all set papers being, as at present, sent from the Admiralty; and at the end of three years every midshipman who has passed the qualifying standard at the last annual examination and the final examination in seamanship before a Board of three captains or commanders (constituted as at present) will become an acting sub lieutenant and return to England. These acting sub-lieutenants will then go to the college at Greenwich for a three-months' course of mathematics and navigation and pilotage, followed by an examination, and afterwards to Portsmouth for a six-months' course in gunnery, torpedo practice and engineering, at the close of which they will be examined, receive their classification (1, 2,

3) in each subject, and, on passing out, be confirmed in the rank of sub-lieutenant.

"Before the period arrives at which the first batch of cadets under the new system have to go to sea, the Board will have considered very carefully and will have decided whether they shall be sent for the whole three years as midshipmen to battleships and cruisers ordinarily commissioned, or whether the first part of this period shall be passed in specially-commissioned training ships. It is quite decided that at whatever period they are posted to ordinarily-commissioned battleships and cruisers compulsory school on board these ships shall cease."

THE CHOICE OF A BRANCH OF THE SERVICE.

"When the young officers, aged nineteen to twenty, have passed out of the college at Portsmouth as sub-lieutenants, and have gained their classification in the different subjects of the examination, their careers for the first time will begin to diverge, and they will be posted to the executive or to the engineer branch of the Navy or to the Royal Marines. As far as possible, each officer will be allowed to choose which branch he will join, but this must be subject to the proviso that all branches are satisfactorily filled. No sub-lieutenant will be compelled to join a branch for which he did not enter as a boy when applying for a nomination, but in giving nominations for competition for entrance to the *Britannia*, preference will (other things being equal) be given to those boys whose parents or guardians declare for them that they will be ready to enter either of the three branches of the Service. The Board of Admiralty will thus have in reserve a means of remedying a surplus or deficiency in either of the three branches, and of insuring that every branch receives a due proportion of the most capable officers.

"Up to this point the young officers' characters have been formed in one school, and all these sub-lieutenants have received as the foundation of their professional education that common knowledge which all alike require. Henceforward their education must be differentiated to make them fit to perform those specialized duties which are the product of modern science."

The following are the regulations for the various branches of the Service:

THE EXECUTIVE BRANCH.

"All the sub-lieutenants who join this branch will go to sea for two years, being warned that they will eventually have to pass a qualifying examination for promotion to the rank of commander in the following subjects:

"Court-Martial Procedure.

"International Law.

"Knowledge of British and Foreign Warships, Guns, Torpedoes, &c.

"Naval History.

"Signals.

"Strategy.

"Tactics and Battle Formations.

"They will not, however, be able to offer themselves for this examination till they have attained five years' seniority in the rank of lieutenant. After two years at sea all these executive sub-lieutenants will be promoted to the rank of lieutenant on gaining the same qualifying watch-keeping certificate as at present. All those who have passed their examinations exceptionally well will, as now, receive accelerated promotion. Those who are selected to be trained as specialists in gunnery, torpedo work or navigation will go to the Royal Naval College at Greenwich for special courses, and an entrance examination will be instituted at Greenwich for these specialists. This examination will carry with it the advantage of enabling the instruction at Greenwich to commence on a fixed basis.

"Every facility consistent with the requirements of the Service will be given to those executive officers who are not specialists to attend voluntary courses at Greenwich in mathematics, naval history, &c., and to study foreign languages at Greenwich, or preferably abroad."

THE ENGINEER BRANCH.

"The sub-lieutenants of this branch will go to the College at Keyham for a professional course, the exact duration of which

will be determined with great care. At the expiration of this course a proportion to be equally carefully determined will be selected to go to Greenwich for a further course while the remainder go to sea. They will then, if found qualified, all be promoted to be lieutenants under the same conditions as the executives. The nature and duration of the special course at Greenwich will be very carefully determined, and an opportunity will be afforded to those officers selected for it to make themselves acquainted with the latest developments of engineering science not only at Greenwich but at the great civil engineering establishments and institutions which are to be found in the country.

"By these arrangements sub-lieutenants of the engineer branch will obtain their step in rank at the same age as the sub-lieutenants of the executive branch, and they will enjoy the same opportunities of accelerated promotion according to the classifications they receive at their previous examinations. The ranks of engineer officers will be assimilated to the corresponding ranks of executive officers, and the engineer officers will wear the same uniform and bear the same titles of rank, *e.g.*, sub-lieutenant (E), lieutenant (E), commander (E), captain (E) and rear-admiral (E). The engineer branch will receive additional pay, and although it is proposed to make the division into the various branches definite and final, every endeavor will be made to provide those who enter the engineer branch with opportunities equal to those of the executive branch, including the same opportunity of rising to flag rank.

"The promotion of future lieutenants (E) and commanders (E) will, as in the case of the executive officers, be by selection and qualifying service, and in the case of lieutenants (E) a qualifying examination for promotion to commander (E) will be instituted; moreover, the proportion of different ranks in the engineer branch will as far as possible be assimilated to that which will be fixed for the executive branch by the committee which is specially considering this question under the chairmanship of Lord Goschen. The endeavor will also be made to find a suit-

able number of high appointments for the flag officers of the engineer branch."

THE ROYAL MARINES.

"After his final examination as sub-lieutenant along with the future and executive and engineer officer the young Royal Marine officer will receive his special military training during the next two years partly at the College at Greenwich and partly at the headquarters of divisions or the depot; the training of all these officers will be extended so as to correspond more closely to the training now received by the young officers of the Royal Marine Artillery; and after this two years' training the young Marine officer will receive the rank and pay of lieutenant of Marines so as to put him financially on an equality with the executive sub-lieutenant. As in the case of the executive lieutenants specially good officers will qualify as gunnery and torpedo lieutenants, provided that they have kept watch at sea for one year, have passed the test examination for qualifying for gunnery and torpedo lieutenants, and been specially selected and recommended.

"For the purposes of promotion and seniority in the corps all these officers will be on one list and not divided into two lists as is now the case with the officers of the Royal Marine Artillery and the Royal Marine Light Infantry.

"The future Royal Marine officer will thus become available for keeping watch at sea and for general executive duties on board ship up to and including the rank of captain of Marines. His rank will be adjusted with that of Naval officers as follows:

Naval.	*Marine.*
Sub-lieutenant, ...	Lieutenant under three years.
Lieutenant, ...	Lieutenant over three years. Captain.
Commander, ...	Major.
Captain under three years .	Lieutenant colonel.

"The above ranks will only hold good while on ships' books. The relative rank when under the Army act will remain as at present.

"On shore, when employed with landing parties and with naval brigades, &c., naval and marine officers will take command over one another, according to their seniority in their corresponding ranks. It will also be arranged that one of the special duties of officers of the Royal Marines will be to advise in respect of the organization, equipment and training of landing parties and work on shore.

"The pay of Royal Marine officers when they are serving afloat will be equalized with the pay of executive officers of the Navy of corresponding rank, and the proportion of different ranks of officers in the Royal Marines will, as far as possible, be assimilated to that to be laid down for executive officers of the Navy by the committee of which Lord Goschen is chairman. The object to be aimed at is that there may be the same proportion of employment in the higher ranks and the same proportionate flow of promotion for the officers of the Royal Marines as for those of the executive and engineer branches of the Navy.

"It may be urged by some that the early naval training of the Marine officer may militate against his subsequent military training, but, in the opinion of the Board, this is not so. The future Royal Marine officer will join his corps at a little later age than at present, but with the great advantage of having been trained to a sea life and having received an excellent naval education. Henceforward the efficient military Marine officer will exist as of old, but with this difference, that from the very outset of his career as such he will be competent to take a much fuller part in the handling and fighting of his ship than his present training has permitted."

TRANSITION STAGE.

Concerning the transition stage these remarks are made:

"The cadet now takes about four and a half years to become an acting sub-lieutenant; under the new system he will become fitted for the general services of the fleet in seven years, while the engineer and Royal Marine officer will require about two years more for their special professional instruction. The new system will be introduced in midsummer, 1903. Supposing (what would not in any event be feasible) that all entries under

the present conditions were to cease immediately, the lists would be recruited for four and a half years by the entries of already existing cadets, but at the expiration of that period there would be an interregnum of two and a half years before entries under the new system became effective, that is, as acting sub-lieutenants; similarly during the next five years the lists would be recruited by engineer students who have already been entered; there would then be an interregnum of five years before the first of the new engineer officers became available; the lists of the Royal Marine Artillery and the Royal Marine Light Infantry would be recruited by candidates already entered for two or one years respectively, and then an interregnum would supervene for six and five years respectively.

"To fill the lists during the interregnum it will become necessary to have recourse to double entries for a period. After the entry of cadets from 12 to 13 has commenced the normal number of entries at 14½ to 15½ must continue to be made for two and a half years, so as to supply executive officers during the interregnum. The normal entries for the Royal Marine Light Infantry must continue for six years and those for the Royal Marine Artillery must continue for five at the present age, while the entry of engineer students at 14½ to 16½ must also continue for five years. The result of this will be that for two and a half years or rather more there must be two sets of cadets, those aged 14½ to 15½ and those aged 12–13. For many reasons it is considered unadvisable that these two sets of cadets should be trained together. It has, therefore, been decided to educate the younger one in the Isle of Wight, where his Majesty has most graciously put at their disposal a portion of the Osborne estate.

"The above is the most convenient method of bridging the period of transition; all the alternative methods have been carefully considered and found to have grave disadvantages."

THE PRESENT ENGINEER OFFICER.

"The Board are confident that the naval engineer officer of the future will maintain to the full the high traditions of the present

engineer branch, but they feel that this scheme would not be complete if it did not include changes designed to harmonize as far as possible the position of the present officers of the engineer branch with the spirit of the future organization. Accordingly, the following changes will be made in the designations of rank:

"Engineer students will become engineer cadets, and the College at Keyham will be known as the Royal Naval Engineering College.

"Assistant engineers for temporary service and assistant engineers will become engineer sub-lieutenants.

"Engineers, chief engineers and staff engineers will become engineer lieutenants.

"Fleet engineers will become engineer commanders.

"Inspectors of machinery will become engineer captains, and

"Chief inspectors of machinery will become engineer rear-admirals.

"The engineer-in-chief will become an engineer rear-admiral, and the Board reserve power to promote the officer holding that high post to the rank of engineer vice-admiral, if thought advisable.

"The average period of reaching each rank will be assimilated, as far as possible, to that of the executive branch, so as to correct the present disparity of age which too often obtains between officers of the two branches of relatively equal rank. (The Board are fully aware of the importance of this question to the officers of other branches than those dealt with in this memorandum, and are now engaged in considering it.) The pay of existing engineer officers will be raised, but no changes will be made in their uniform or in the regulations which define their duties or in the provisions of the Naval Discipline Act.

"The Board have given their careful and earnest consideration to all the suggestions which have been made from a variety of quarters for further changes affecting the present engineer officers. The decision at which they have arrived is, they are convinced, that most conducive to the interests of the Service as a whole."

THE PRESENT MARINE OFFICER.

"The comparative non-utilization of the services of the Marine officer on board ship has long been a matter of regret on the part of successive First Lords and successive Boards of Admiralty; but his want of early sea training and his want of knowledge of the general duties of the ship when first embarked have hitherto rendered the young Marine subaltern unable to take any responsible part either in the general work or in the navigation of the ship. The sole reason, therefore, of the comparative non-utilization of the Marine officer's services on board ship has been his purely military training. This condition of affairs has naturally been discouraging in the extreme to the young Marine officer himself, and it has been detrimental to the Navy, which has found itself deprived, in respect of many important matters, of the services of a valuable officer.

"The new scheme will alter all this; but the present question is, How can the services of the existing Marine officer be better utilized on board ship? It has been decided that the present Marine officers shall be made available for employment in gunnery and torpedo duties, in harbor work such as officer of the guard, and generally in taking a more active part in the duties of the ship. They will, moreover, be held eligible for equal consideration with naval officers for employment in Admiralty departments, such as the Department of the Director of Naval Ordnance and the Naval Ordnance Store Department, and as members of the Ordnance Committee. They are already, to the great advantage of the Service, largely utilized in the Naval Intelligence Department and generally in connection with the intelligence work of the fleet. Their employment in this sphere of work will continue to be developed, and it is also thought that a much-felt want in respect of the supply of interpreters may be remedied by holding out inducements and giving facilities to the present Marine officers to qualify as such. The question of the rates of pay of the existing Marine officers is being carefully considered, with a view to its equitable adjustment to the special circumstances of their employment.

"It has been suggested to the Board that the present would

be an opportune moment for the amalgamation of the Royal Marine Artillery and the Royal Marine Light Infantry. The Board, however, feel that in the case of a corps with the old traditions of the Royal Marines great respect must be paid to sentiment wherever it does not clash with a reform essential to the good of the Service. This is not so in this case, and the question of future amalgamation will be left to solve itself in the expectation that the general opinion of the corps will be found to harmonize with the logic of hard facts. As the future Marine officers will be on one list, and as their gunnery training will be as far as possible assimilated to the present training of the Artillery officers, and as the future gunnery and torpedo lieutenants of the corps will correspond as specialists to the present Artillery officers, the future impediments in the way of amalgamation would seem to consist mainly in the name and in the color of the uniform. As regards the uniform time will solve the problem, but as regards name I cannot imagine one more universally honored than that of the Royal Marines."

BETWEEN NAVY AND ARMY.

"The great difficulty which has always confronted the Board of Admiralty in respect of this famous corps has been that of finding a sufficient amount of employment, and employment of a sufficiently interesting and engrossing character for the general officers. This difficulty has arisen from the fact that the Royal Marines, owing to their special history, have not been able to enjoy the advantages and opportunities of employment in the higher ranks either of officers of the Navy or of the Army. They have not been able to enjoy the advantages of corresponding officers of the Navy because they have never had the training to command ships, squadrons or fleets. They have not been able to enjoy the opportunities of corresponding officers in the Army because they have not formed part of that Army and the War Office has regarded the officers of the Army as having the first claim upon it for employment. Time has wrought many changes in the conditions of service both in the Royal Navy and in the Royal Marines, and the current of events has set the Royal Marines more towards the Navy than towards the Army.

The Royal Navy is indispensable to the Royal Marines and the Royal Marines are indispensable to the Royal Navy, and I hope that the officers both of the Navy and of the Marines will realize more and more in the future that the Royal Marines and the Royal Navy are but two great parts of the one sea service on which this country depends.

"If at any future time an even closer union between the Navy and the Marines becomes possible than that now contemplated, it will be necessary that the Royal Marines should come wholly under the Naval Discipline Act (amended to meet the case) and cease to be partly governed under the Army Act."

WARRANT OFFICERS, PETTY OFFICERS AND MEN.

"Nearly half a century has passed since the introduction of the continuous-service system, and it is scarcely possible to exaggerate the value of that reform to the Navy. It is no disparagement to the splendid fighting qualities and the daring seamanship of the sailors of bygone days to assert that the lower deck of today has added to its fame for handiness and discipline a character for sobriety and respectability previously unknown. In the old days there was no assurance of a career to the men; there was no certainty to the State that on an emergency the men required to man the fleet for war would be forthcoming. Today the manning of the fleet can be organized with mathematical precision, and every well-behaved man can rely on continuous employment, followed by provision for old age.

"Consequently, the Navy has become to the men what it always has been to the officers, the profession and devotion of a lifetime, and a corresponding responsibility rests on the Board of Admiralty to see that as the circumstances of the time change a career commensurate with this fact remains open to them, and that their training and education is as fully adapted to the work they have to perform as that of the officers.

"In this connection I am able to announce that the following principles have been agreed upon by the Board:

"1. That the masted training squadron being abolished, and the importance of gunnery and the use of machinery daily in-

creasing, the present is an opportune moment for reviewing the whole course of training.

"2. That specialization which must be continuous and systematic becomes more and more urgent, and this fact must be borne in mind in considering the system of training. This does not, of course, mean that every man should have a specialized training.

"3. That an accumulation of men in barracks on shore is a new feature in naval life, and that the utmost care must be taken to establish a system whereby the time of the men in barracks may be utilized to the greatest advantage of the Navy and themselves.

"4. That the lines on which the gunnery and torpedo schools may best be developed should now be settled, especially as the proposal has been brought forward that the torpedo schools should imitate the example of the gunnery schools in forming great shore establishments."

Detailed Plan.

"The detailed plan on which these general principles will be put into operation will be most carefully considered, and I can only at present state that it has been decided not to build great barracks for the torpedo schools, or to transfer them to establishments ashore, and further indicate some of the decisions that have been taken affecting the various ratings and ranks:

"It is proposed to enter between fourteen and sixteen years of age boys to be called 'boy artificers,' who will be most carefully trained, and whose engagement will be to serve for twelve years continuously from the age of eighteen.

"In this manner a second source of supply will be formed for the ever-increasing needs of the fleet in respect of engine-room artificers.

"2. It has long been a complaint on the part of the engineer branch that an engineer officer on board each big ship is employed in clerical duties. It is proposed to remedy this by establishing a non-substantive rating of engineer's writer, and the engine-room complement will in future include this rating, to be held preferably by men of the stoker class.

"3. The engine-room complement of every sea-going ship will

also include the non-substantive rating of 'yeoman of stores,' to be held by a chief or leading stoker.

"4. Young and promising leading stoker mechanics, not over thirty years of age, will be eligible for the new rating of 'mechanician'; selected candidates will be required to pass the educational examination established for the rating of engine-room artificer; they will then receive a careful further training, at the end of which it will be sufficient if it is shown that the men possess the requisite skill to give valuable aid in the ordinary repairs and casualties of an engine room or stokehold; 'mechanicians' will take rank as chief petty officers immediately after engine-room 'artificers,' and be granted suitable rates of pay, increasing with length of service.

"The stokers have been recently placed on an equality with the seamen and marines in respect of the grant of a free kit on entry. This concession and the addition of these three new ratings will, it is hoped, greatly augment the attractiveness of this Service."

"5. The numbers of artificer engineers and chief artificer engineers will gradually be largely increased.

"6. There has been for some time past a deficiency in the signal ratings of the fleet. To remedy this an increase has been made in the pay of the class by the grant of 6d. a day to a large percentage of the higher ratings and thus the signal ratings have been put upon an equality with the gunnery and torpedo ratings, and the expected result of attracting the required number of volunteers for the signal branch of the service has been produced.

"7. There has for some time past been a strong feeling that the appearance, the system of training and the standard of efficiency of naval bandsmen are unsatisfactory, and that an unfair proportion of the cost of naval bands falls upon the officers.

"The Board have now under consideration a plan for the complete reorganization of naval bands, the effect of which it is believed will be to bring substantial relief to the officers in the matter of expense.

"8. The chief petty officers of the fleet have long felt it a

hardship that, notwithstanding the great importance and responsibility of their position, they receive no higher rate of pension than a first-class petty officer.

"The Board are glad to be able to announce that it has been decided to increase the pensions of chief petty officers by ½d. a day for each year's service in chief petty officer's rating subsequent to the completion of their first engagement. This apparently small change will alone entail an eventual charge on naval funds of no less a sum than £73,000 a year."

Promotion of Lieutenants from Warrant Rank.

"The Board have long been anxious to see their way to promote a certain proportion of gunners, boatswains and carpenters to the commissioned ranks, and thus afford to the lower deck of the Navy, opportunities of rising similar to those which the rank and file of the Army enjoy by the opportunity of promotion to the rank of quartermaster or riding-master. It is accordingly a great satisfaction to them to be able to announce that a list has already been drawn up of sixty appointments to which these officers can be promoted, and that the proportion of each branch of warrant officer which will be promoted to lieutenant will be the same, as near by as possible, as the proportion of each of those branches to the combined total of the warrant officers' list. A proportionate number of commissions will also be allotted and employment found on the same principles for the warrant officers of the engineer branch. If the officers promoted are selected from among the seniors and thus have not too many years to serve to complete their age for retirement, no difficulty will arise as to their continued employment, or as to the avoidance of half-pay which they could not afford."

Conclusion.

The memorandum ends thus:

"Such in outline are the proposals which are designed not only to improve the position, prospects and pay of the warrant officers, chief petty officers and men of the fleet, but also to improve

their training and to complete the organization of the fleet where it is at present at all defective in its personnel. Due care has been taken that these changes shall not conflict but harmonize with the recommendations which will presently be made by the committee, of which Sir Edward Grey is chairman, in respect of the manning and reserves of the fleet.

"Important, however, as is the part of the scheme which affects the men, that which affects the officers is still more important. The cardinal feature of the scheme is the homogeneous training of executive, engineer and Marine officers. The policy of the Board is to create a body of young officers who at the moment of mobilization for war will be equally available for all the general duties of the fleet and to consolidate into one harmonious whole the fighting officers of the Navy.

"Difficulties doubtless there will be in carrying this part of the scheme into full effect, but those difficulties have been foreseen, and they will be met. The advantages to the Navy of the realization of the scheme will be inestimable and permanent; the difficulties will be secondary and transient. The Board are conscious that on them alone rests the responsibility, and that they alone have the advantage of knowing all the conditions which govern the problem. The step which they have taken is a long step forward to increased strength, and for aid in the task of consolidating their work they rely with supreme confidence on the loyalty to the Service of the officers of the Royal Navy and of the Royal Marine."

CIRCULAR LETTER TO THE FLEET.

The following circular letter has been issued to the fleet:

ADMIRALTY, *Dec. 19, 1902.*

My Lords Commissioners of the Admiralty, having had under their consideration the present system of the entry, education and training of executive and engineer officers of the Navy and officers of the Royal Marines, have decided to introduce the following changes:

I.

All the above-mentioned officers will in the future enter the Service as naval cadets, under identical conditions, between the ages of twelve and thirteen. Entry will be by nomination and a limited competitive examination. In the nomination of candidates preference will, other things being equal, be given to those boys whose parents or guardians declare for them that they are prepared to enter any one of the three branches of the Service at the termination of their probationary period of training afloat. The examination (the syllabus of examination will be amplified later) will include:

PART I.

1. English (including writing from dictation, simple composition and reproduction of the gist of a short passage twice read aloud to the candidates).
2. (*a*) History and (*b*) geography—
   (*a*) History (simple questions in English history and growth of the British Empire).
   (*b*) Geography (simple questions, with special reference to the British Empire).
3. French or German (importance will be attached to the oral examination).
4. (*a*) Arithmetic and (*b*) algebra—
   (*a*) Arithmetic (elementary, including vulgar and decimal fractions).
   (*b*) Algebra to simple equations, with easy problems.
5. Geometry (to include the subject-matter of the first book of Euclid, or its equivalent in experimental geometry and mensuration. The use of instruments and of algebraical methods will be allowed).

PART II.

(One only to be taken.)

6. Latin (easy passages for translation from Latin into English and from English into Latin, and simple grammatical questions).

7. A second modern language (of which, if not French or German, notice must be previously given) or an advanced examination in the language selected under Part I.
8. Experimental science (easy questions, with the object of testing practical knowledge and powers of observation).

The list of successful candidates will be published in alphabetical order.

The cadets on entry will all receive the same education and training until they have passed for sub-lieutenant at the age of nineteen to twenty. Of this period of training the first four years will be spent in the *Britannia* establishments, the instruction comprising an extension of the former *Britannia* course and a thorough elementary instruction in physics and marine engineering, including the use of tools and machines. Instruction will also be carried out afloat in small vessels attached to the training establishments for that purpose.

2. After four years in the training establishments all cadets will go to sea, time gained on passing out counting as at present. The instruction of midshipmen while serving in sea-going ships will, as regards seamanship, be given as at present by an executive officer deputed by the captain, and in other respects will, under the general supervision of the captain, be carried out by the engineer, gunnery, marine, navigating and torpedo lieutenants of the respective ships. They will be examined annually in seamanship, navigation and pilotage, gunnery, torpedo and engineering. At the end of three years every midshipman who has passed the standard at the last annual examination and the final examination in seamanship before a Board constituted as at present will become an acting sub-lieutenant and, if abroad, will return to England.

3. Acting sub-lieutenants will go to the R. N. College, Greenwich, for a three months' course in mathematics, navigation and pilotage, followed by an examination, and then to Portsmouth for a six-months' course in gunnery, torpedo and engineering. At the end of the course they will be examined and classed, and on passing will be confirmed as sub-lieutenants.

4. On being confirmed as sub-lieutenants these officers will be

distributed between the executive and engineer branches of the Navy and the Royal Marines. As far as possible they will be allowed to choose to which branch or service they will devote themselves, subject to the provision that all alike can be satisfactorily filled; but no officer will be posted to a branch or service for which he did not volunteer through his parents and guardians when asking for a nomination.

5. All sub-lieutenants of the executive branch will go to sea for two years, at the end of which time they will be eligible for promotion to lieutenants, provided they have obtained the necessary certificate of ability to keep watch. Those who have passed exceptionally good examinations will recieve accelerated promotion under the same regulations as at present.

6. Lieutenants with the necessary sea service, who are selected to be trained as specialists in gunnery, torpedo or navigation, will go to the R. N. College, Greenwich, for special courses, and an entrance examination will be instituted at Greenwich for these specialists.

Every facility consistent with the requirements of the service will be given to those executive officers who are not specialists to attend voluntary courses at the R. N. College, Greenwich, in naval history, mathematics, &c., and to study foreign languages at Greenwich or, preferably, abroad.

7. All lieutenants entering the service under the new scheme will be required at any time after attaining five years' seniority, but not before, to pass a qualifying examination for promotion to the rank of commander in the following subjects:

Court-Marshal Procedure.

International Law.

Knowledge of British and Foreign Warships, Guns, Torpedoes, &c.

Naval History.

Signals.

Strategy.

Tactics and Battle Formation.

8. All sub-lieutenants of the engineering branch will go to the college at Keyham for a course of professional instruction,

at the end of which time they will be eligible for promotion to lieutenants (E) under the same conditions as regards accelerated promotion as the executive sub-lieutenants. After leaving Keyham the most promising officers will be selected to go to Greenwich for a further special course, which will include an opportunity of studying at large civil engineering establishments and institutions, while the remainder will go to sea.

9. Lieutenants (E) will be eligible for promotion to commanders (E), captains (E), and rear-admirals (E). Promotion of future lieutenants (E) and commanders (E) will be by selection, the former, after attaining five years' seniority, being required to pass a qualifying examination for promotion to the rank of commander (E).

The pay which officers of the new engineering branch will receive is shown in Table A.

10. All sub-lieutenants who after their final examinations enter the Royal Marines will spend the next two years in acquiring military training, partly at the headquarters of divisions or the depot, and partly at the R. N. College, Greenwich. The training of all these officers will be extended so as to correspond more closely to the training now received by young officers, R. M. A. Specially qualified officers of Marines will be eligible for employment as gunnery and torpedo lieutenants, provided they have kept watch at sea for one year, have passed the test examination and been specially selected and recommended.

11. The future Marine officers, whether posted to the R. M. A. or R. M. L. I., will all be on one list for seniority and promotion in the corps. All Marine officers (up to and including the rank of captain of Marines) will be available for keeping watch at sea, and for general executive duties afloat.

The relative ranks will be adjusted as follows:

Naval.	Marine.
Lieutenant, . .	{ Lieutenant over two years. { Captain.
Commander, . .	Major.
Captain under three years,	Lieutenant Colonel.

The above will hold good only while these officers are on ship's books, the relative rank when under the Army Act remaining as at present.

The pay of future officers of the Royal Marines is shown in Table B.

12. On shore, when employed with landing parties in Naval brigades, &c., Naval and Marine officers will take command of one another, according to their seniority in their respective ranks.

II.—The Transition Stage as Regards Entry.

13. The new system of entry will be introduced at midsummer, 1903.

As cadets entered under this system will not become effective for service in the fleet for seven years from the date of entry, the normal number of entries under the existing system will continue as follows:

Cadets for two and a half years.
Engineer students for four years.
R. M. A. for five years.
R. M. L. I. for six years.

The last examination for entry of cadets under the existing system will be held in November, 1905.

14. A portion of the buildings and land at Osborne will be utilized, with his Majesty's gracious permission, for an additional training establishment, to which suitable small vessels will be attached for the instruction of cadets in engineering and navigation.

III.—Alteration with Regard to Existing Engineer Officers.

15. It has been decided to make at once the following alterations in rank:

The engineer-in-chief of the fleet and the chief inspectors of machinery to be styled engineer rear admirals. The Board reserve power to promote the engineer-in-chief to be engineer vice admiral.

Inspectors of machinery to be styled engineer captains;

Fleet engineers to be styled engineer commanders;

Staff engineers, chief engineers and engineers to be styled engineer lieutenants;

Assistant engineers to be styled engineer sub-lieutenants;

Assistant engineers for temporary service to be styled engineer sub-lieutenants for temporary service;

The rank of probationary assistant engineer to be abolished;

Engineer students to be styled engineer cadets, and the Naval Engineering College is to become the Royal Naval Engineering College.

16. The average period of reaching each rank will be assimilated as far as is possible to that of the executive branch.

The new scale of pay of existing engineer officer will be as shown in Table C.

IV.—The Existing Marine Officer.

17. The services of the present Marine officers will be utilized for employment in gunnery and torpedo duties and harbor work, such as officer of the guard, &c., and generally in taking a more active part in the duties of the ship.

They will be eligible for consideration for employment in the Naval Ordnance and Naval Ordnance Store Departments of the Admiralty, and as members of the Ordnance Committee.

The new scale of pay of existing Marine officers will be as shown in Table D.

The changes in pay shown in the annexed tables will take effect from April 1, 1903.

By command of their Lordships:

Evan Macgregor.

To all commanders-in-chief, captains, commanders and commanding officers of His Majesty's ships and vessels, at home and abroad.

Table A.—Future Engineer Officers.

Rank.	Pay per diem.
Lieutenant (E), ...	12s. 0d.
of 4 years, ...	14 0
8 years, ...	16 0
10 years, ...	17 0
12 years, ...	18 0
14 years (maximum), . .	20 0

Rank.	Pay per diem.
Commander (E),	24 0
of 2 years,	27 0
4 years,	30 0
6 years,	33 0
Captain (E),	35–40 0
Rear Admiral (E),	60 0

TABLE B.—FUTURE MARINE OFFICERS.

Rank.	Pay per diem.
Lieutenant,	10s. 0d.
after 4 years in rank,	11 0
Captain,	12 0
after 1 year in rank,	13 0
5 years in rank,	15 0
Major,	20 0
after 2 years in rank,	22 0
4 years in rank,	24 0
6 years in rank,	26 0
Lieutenant Colonel,	30 0
after 2 years in rank,	33 0
4 years in rank,	36 0

Colonels second commandant will receive pay of rank and an additional allowance of 5s. per diem.

Colonels commandant will receive pay at present rates, with an additional allowance of 12s. a day.

TABLE C.—EXISTING ENGINEER OFFICERS.

New Ranks and Scale of Pay.

Rank.	Pay per diem.
Engineer Lieutenant,	10s. 0d.
after 2 years,	11 0
4 years,	12 0
6 years,	13 0
8 years,*	16 0

*This pay of 16s. a day, together with the right to wear the uniform of the increased rank of engineer lieutenant of eight years' seniority, will be dependent on his obtaining a qualifying certificate and on being selected.

Rank.	Pay per diem.
Engineer Lieutenant, . 10 years, . . .	17 0
12 years, . . .	18 0
14 years, . . .	20 0
Engineer Commander, ...	24 0
after 2 years, . . .	27 0
4 years, . . .	30 0
6 years, . . .	33 0
Engineer Captain, ...	35–40 0
Engineer Rear Admiral, ...	60 0

TABLE D.—EXISTING MARINE OFFICERS.

New Scale of Pay.

Rank.	Artillery. Pay per diem.	Infantry. Pay per diem.
Lieutenant, ...	6s. 4d.	5s. 11d.
after 3 years, . .	7 5	7 0
Captain, ...	12 1	11 7
after 1 year, . . .	12 7	12 1
5 years, . . .	13 1	12 7
8 years, . . .	14 7	14 1
Major, ...	16 1	15 7
after 2 years, . . .	17 6	17 6
4 years, . . .	18 0	18 0
6 years, . . .	18 6	18 6
Lieutenant Colonel, . . .	21 0	21 0
after 2 years, .	21 9	21 9
4 years, .	22 6	22 6

Colonels second commandant will receive pay of rank and an additional allowance of 5s. per diem.

Colonels commandant will receive pay at present rates, with an additional allowance of 12s. a day.

TO CANDIDATES FOR COMMISSIONS.

The following are the regulations for the new scheme of entry of naval cadets who are candidates for commissions as executive and engineer officers of the Navy and officers of the Royal

Marines which will come into operation in July, 1903. The regulations as to entry under old scheme, which will remain in force for candidates of the ages of 14½–15½ until November, 1905, are issued separately.

1. All officers for the executive and engineer branches of the Royal Navy or for the Royal Marines will enter the Service in future as naval cadets under identical conditions between the ages of twelve and thirteen, and will be educated and trained together until passing as sub-lieutenants at the age of 19–20.

2. Appointments to naval cadetships will be made by limited competition after nomination.

In the nomination of candidates preference, other things being equal, will be given to those boys whose parents or guardians declare for them that they are prepared to enter any one of the three branches of the Service at the termination of their probationary period of service afloat.

As far as possible each officer will be allowed to choose which branch or service he will join, but this must be subject to the proviso that all alike are satisfactorily filled. No officer, however, will be compelled to join a branch or service for which he did not volunteer as a boy when his nomination was granted.

Candidates must be of pure European descent, and the sons either of natural-born British subjects or of parents naturalized in the United Kingdom. If any doubt arises upon this question, the burden of clear proof that he is qualified will rest upon the candidate.

3. The conduct of the educational examination of candidates is under consideration.

4. All nominations of candidates for naval cadetships are made by the First Lord, with the exception of a limited number which are at the disposal of individual members of the Board, and of the Secretaries to the Board of Admiralty.

Applications for nominations should be addressed to the Assistant Private Secretary to the First Lord, and should not be made until the candidate has reached eleven years of age.

A flag officer or a commodore, first class, appointed to the chief command of a station or to a separate command, and a

captain on first appointment as such to the command of a ship, will be allowed to nominate one candidate, provided the privilege is exercised within six months of appointment and that the candidate is not less than eleven years of age when nominated. The examination of candidates will not take place until they are eligible by age under clause 7.

No captain will be entitled to nominate more than one candidate during the time he holds the rank of captain, but a flag officer or a commodore, first class, may claim the privilege each time he is appointed to a command as above.

In the event of a candidate's nomination being cancelled before he has commenced the examination, the officer who nominated him will be allowed to select another candidate for the same or following examination.

5. The nominations will be made three times a year, six weeks before the date fixed for the examination of candidates.

6. The examinations will be held at the end of March, July and November, and the appointments will date from the 15th May, 15th September, 15th January following, respectively, as under the old scheme.

The first examination will be held in July, 1903, and further particulars as to the place and time of the examination will be published later.

7. A candidate will not be eligible for the examination in March who is less than twelve or more than thirteen years of age on the 15th May following, nor for the examinations in July or November, who is not within those limits of age on the 15th September or 15th January following, respectively.

8. Every candidate must be in good health and free from any physical defect of body, impediment of speech, defect of sight or hearing, and also from any predisposition to constitutional or hereditary disease or weakness of any kind, and in all respects well developed and active in proportion to his age. Before undergoing the literary examination he will be required to pass the medical examination according to the prescribed regulations, and must have been found physically fit for the Navy.

9. The candidate will be required to produce (1) a registrar's

certificate of the date of his birth or a declaration thereof made before a magistrate (a certificate of baptism will not be accepted); (2) a certificate of good conduct from the masters of the school or schools at which he may have been educated during the two previous years, or, if educated at home, from his tutor or the clergyman of the parish in which he resides; and (3) proofs of good health.

10. Candidates will be examined in the following subjects (the syllabus of examination will be amplified later):

PART I.

1. English (including writing from dictation, simple composition and reproduction of the gist of a short passage twice read aloud to the candidates).
2. (*a*) History and (*b*) geography—
   (*a*) History (simple questions in English history and growth of the British Empire).
   (*b*) Geography (simple questions, with special reference to the British Empire).
3. French or German (importance will be attached to the oral examination).
4. (*a*) Arithmetic and (*b*) algebra—
   (*a*) Arithmetic (elementary, including vulgar and decimal fractions).
   (*b*) Algebra to simple equations, with easy problems.
5. Geometry (to include the subject-matter of the first book of Euclid, or its equivalent in experimental geometry and mensuration. The use of instruments and of algebraical methods will be allowed).

PART II.

(Only one to be taken.)

6. Latin (easy passages for translation from Latin into English and from English into Latin, and simple grammatical questions).

7. A second modern language (of which, if not French or German, notice must be previously given) or an advanced examination in the language selected under Part I.
8. Experimental science (easy questions, with the object of testing practical knowledge and powers of observation).

The syllabus of examination will be simplified later.

The list of successful candidates will be published in alphabetical order.

11. For all cadets entered under these regulations the payment will be at the rate of £75 per annum for the period under training, to be paid every term in advance to the cashier of the Bank of England on receipt of claim from the Accountant-General of the Navy. But the Lords Commissioners of the Admiralty reserve the power of selecting from among the cadets entered at each examination a limited number, being sons of officers of the Navy, Army or Marines, or of civil officers under the Board of Admiralty, with respect to whom the annual payment will be £40 only. In this selection their Lordships will have regard solely to the pecuniary circumstances of the cadet.

Applications for the reduced scale must be received at the Admiralty not later than January 1, May 1 and September 1.

Parents or guardians are further required to make a private allowance of £50 per annum to cadets from the expiration of their period of training until they reach the rank of acting sub-lieutenant.

12. In addition to the annual payments mentioned in the foregoing paragraph, the parent or guardian will be charged with the personal expenses incurred by the cadet for washing, repairing boots and clothes, hair-cutting, pocket money, &c.

13. The period of training in the training establishments will be four years; there will be three terms in each year. The first term of each year will be approximately from January 14 to April 14, the second from May 5 to August 5, and the third from September 16 to December 16.

The vacations will be four weeks at Christmas, three weeks at Easter and six weeks at midsummer.

14. Examinations will be held at the end of the second and fourth years of training. Cadets who fail to pass in such examinations will be ordered to be withdrawn.

15. Reports of progress will be made to the Admiralty at the end of each term. Cadets who are reported at the end of any term as having made unsatisfactory progress through idleness or want of attention will be "warned," and in the event of a second report to the same effect being received they will be liable to be discharged.

16. Reports of conduct will be made to the Admiralty at the end of each term or at any time during the period of training, if considered desirable. Cadets who are reported to the Admiralty at any time for unsatisfactory conduct will be "warned," and should they again be reported they will be liable to be discharged. Any cadet, however, who is reported for unsatisfactory conduct during his final term will be liable to be discharged without being allowed to present himself at the examination for passing out of the training establishments.

17. Any cadet who shall at any time appear to their Lordships to be unfit for the naval service, for any reason whatever, will be removed from the training establishments, and it must be understood that this rule will apply to those who are considered unfit from insufficient physical development or weakness of constitution, though no actual organic disease may have been developed.

18. It is to be distinctly understood that the period of training in the training establishments is a time of probation, and the parent or guardian of every cadet will be required to sign a declaration (on the admission of the cadet to the training establishments) to the effect that he shall be immediately withdrawn on the receipt of an official intimation of his being considered unfit for the Navy.

19. Cadets will, on passing out of the training establishments, rank according to the amount of sea time they obtain at their final examination, and those who obtain equal amounts of sea time will rank in the order of merit in which they pass out of the training establishments.

Sea time will be awarded according to the following scale:

.....	Mathematics and navigation.	Extra subjects.	Seamanship.	Conduct.
1st class.....	1 month	1 month	1 month	Very good, 1 month.
2d class.....	½ month	½ month	½ month	Good, ½ month.

20. The parent or guardian of every cadet will be required to provide outfit under the regulations in force.

21. No pay will be allowed by government to cadets in the training establishments. The pocket money allowed to cadets will be charged to the parents.

22. On leaving the training establishments cadets will go to sea. At the end of three years, and after passing the necessary examinations, midshipmen will be eligible to pass for acting sub-lieutenant, and on passing will be discharged to the Royal Naval College, Greenwich.

23. On the conclusion of their examinations sub-lieutenants will be distributed between the executive and engineer branches of the Navy and the Royal Marines.

By command of their Lordships.

EVAN MACGREGOR.

Admiralty, December 19, 1902.

TO PARENTS AND GUARDIANS.

The Secretary of the Admiralty announces, for the information of parents and guardians, that the new scheme of entry and training of executive and engineer officers of the Royal Navy and officers of the Royal Marines, by which all candidates for commissions will enter as naval cadets, under identical conditions, between the ages of twelve and thirteen, will be introduced in July, 1903, when the first examination will be held.

During the period of transition from the existing to the new regulations the examination of candidates will be held under both regulations three times a year at the customary dates.

Under the new scheme a candidate will not be eligible for the examination in July who is less than twelve or more than thirteen years of age on September 15 following, nor for the examinations in November or March who is not within those limits of age on January 15 or May 15 following, respectively.

Under the old scheme the last examination for naval cadets entering the *Britannia* at the ages of 14½–15½ will be held in November, 1905.

The last examination for engineer students entering the Engineer Students' Training College, at Keyham, of the ages of 14½–16½ will be held in March, 1906.

The last examination of candidates for commissions in the Royal Marine Artillery of the ages of 16–18 will be held in June, 1908.

The last examination of candidates for commissions in the Royal Marine Light Infantry of the ages of 17–19 will be held in June, 1909.

N. B.—The ages of entry in the Royal Marines under the old scheme must be regarded as subject to possible revision in consequence of recent changes in the Army regulations.

The medical examination of candidates under the existing scheme will be conducted as before. Under the new scheme all candidates will be medically examined by the Medical Director General of the Navy in accordance with the recent practice as regards candidates for entry in the *Britannia*.

Admiralty, 24th December, 1902.

SUPPLEMENTARY STATEMENT OF LORD SELBORNE.

"In reply to inquiries that have been made I have to say that the words in my memorandum to the effect that the division of the sub-lieutenants into the three branches, executive, engineer and Royal Marine, shall be definite and final mean exactly what they say as regards the intention of the present Board. The point could not be left doubtful. Either there will be interchangeability hereafter between the three branches or there will not. Either an engineer officer, for instance, will be able to rise

to the command of a ship or squadron or he will not. These are questions which time and experience alone can answer, and the Board, in framing the present scheme, had to be prepared for either event. Their object is to leave future boards unfettered to act in this matter for the greatest advantage of the Service. If it had now been announced that there would hereafter be complete interchangeability, and that an engineer officer, for instance, could rise to command a ship, future Boards would have been bound by this pledge to cadets entering the service, and never could have gone back on it, whatever might be the teaching of experience. The announcement made that the division will be definite and final can apply only to the principles by which the present Board must be guided in providing recruits for the three branches, and leaves a future Board perfectly free to relax the rule if it thinks fit; but it follows, of course, that, unless a future Board does think fit in the interests of the Service to relax the rule, the division will remain definite and final, and there will be no interchangeability. No useful purpose can be served by speculating on what a Board may do ten years hence or more; the essential thing is that they should be free to do whatever, in their time, is best for the service. This essential freedom of action will be secured by the present scheme."

CORRUGATED FURNACES.

TESTS OF BROWN'S IMPROVED TYPE.

By Lieut. Commander W. C. Eaton, U. S. Navy, Member.

In view of the tendency towards increased pressures for marine boilers, and as the furnaces are the weak links in the chain of boiler construction, the Bureau of Steam Engineering of the Navy Department has given every encouragement to inventors and manufacturers to produce the furnace that will be least liable to fail by collapsing. The series of tests described in the following article were made on February 3, 1903, and conducted in the presence of the Supervising Inspector General and full Board of Supervisors of the Steamboat Inspection Service. There were also present a hundred or more representatives of various shipbuilding companies and manufacturing interests. The writer was officially directed by the Engineer-in-Chief of the Navy to observe and report upon the tests as a representative of the Navy Department.

Brown's improved corrugated furnace differs from all other corrugated furnaces heretofore built, in that a special method is pursued in its manufacture and in that the material increases in thickness uniformly from the center of each flat to the apex of the corrugations. Accompanying this article are sketches which show both the construction of the furnaces and also the method of preparing them for the tests. These sketches are, however, defective, in that they show the metal to be apparently of the same thickness for some distance along the inner flats, while, as before stated, the metal gradually thickens from the center of each flat to the apex of the corrugations.

In all four of the furnaces tested the increase in thickness at the apex of the corrugations was $\frac{3}{16}$ of an inch, the depth of all corrugations being $1\frac{5}{8}$ inches. These two dimensions are, as stated

by the representative of the Brown Company, the standard for all furnaces as built by that firm.

The particular furnaces which were tested, were made by John Brown & Co., Ltd., of Sheffield, England, and are known as "Brown's Improved Corrugated Furnaces." No furnaces of this kind have yet been made in the United States, and the object of these tests was to determine a constant for use in the formula limiting the working pressure, the expectation being that such a constant would be allowed as would invite the manufacture of these furnaces in this country. As soon as the constant has been fixed and the furnaces accepted, the American agents state that it is proposed to establish an American plant which will be, say the agents, "American in every respect." As the manufacture of corrugated furnaces in this country is now being carried on by only one company, the desirability of the establishment of a competing firm, and its value to American commerce, can hardly be questioned.

The points of difference in the manufacture of this furnace and other corrugated furnaces, as well as the claims for superiority over the latter, as set forth by the American agents, are here given in full, the writer, of course, disclaiming any responsibility for the particular claims advanced.

The first claim of superiority made by the owners of the Brown design over the furnace in most common use in the Navy is based upon the following statement:

"The ordinary furnace is made from a sheet of boiler plate, rolled and welded into a cylinder, and afterwards corrugated into the desired shape. Taking a furnace 30 inches in diameter with a shell $\frac{1}{2}$ inch thick, this shell would be expanded at each rib or corrugation to a diameter 4 inches greater on the outside than the original diameter of the shell, which means that the metal has been stretched at each corrugation 4 inches in a length of 30 inches.

"It is therefore apparent, and actual measurements bear out the statement, that the metal, while $\frac{1}{2}$ inch thick at the outset, is considerably thinner at the top of the rib than at any other point of the shell. In other words, the metal is not of uniform thick-

ness. Measurements which have been taken show a difference of $\frac{1}{16}$ inch between the thickness in some parts of the shell and the thickness in the top of the rib. The object of these ribs or corrugations is to give strength and stiffness as against collapsing pressures, and consequently, if uniform strength is to be secured, the furnace should be as thick at the top of these corrugations as at any other point, or even thicker.

"The Brown furnace is made from a rolled section. In other words, there is no corrugating done. The section as it comes from the plate-mill rolls is an exact cross section of the furnace after it is completed, and the material at the top of the rib is made very slightly thicker than it is at any other point, so that extra thickness and extra strength are given at the point where most needed; or, if so desired, the thickness of the plate can be guaranteed absolutely uniform throughout the furnace, which cannot be done by any other known method of manufacturing furnaces. Again, by making the furnace from a rolled section, the section is so rolled that the plain ends, which are afterwards flanged or widened, are made thicker than the balance of the plate, with the result that after flanging they are of the same thickness as the other portions of the furnace. This is not possible when the furnace is made from a welded cylinder of boiler plate, as of course the flanging or expanding of the ends thins the material, so that the very parts of the furnace where the riveting is done and where we should have extra strength, instead of being as thick as the other parts of the furnace, are thinner.

"An ordinary corrugated furnace, being thinner at the top of the corrugation, as above mentioned, is much too elastic; so that with each contraction and expansion it becomes weaker, until the elasticity of the metal is at last destroyed, and the furnace comes down. The Brown furnace, which has been used in England for years, has demonstrated itself to be sufficiently elastic to conform to all requirements, and yet sufficiently stiff not to contract and expand to too great an extent, and consequently it does not come down when an ordinary corrugated furnace would."

The second claim of superiority is, like the first, based on improved method of manufacture.

"The process of welding a sheet of boiler plate into a cylinder and then corrugating it, which is the method pursued in the manufacture of other forms of corrugated furnaces, necessarily distorts and punishes the metal, giving a furnace full of unequal strains, which no amount of annealing will entirely remove. The Brown plate, having been rolled originally to the proper shape, merely needs to be rolled into a cylinder and welded, and consequently does not have, and never did have during the process of manufacture, any unequal strains."

The third claim made is that the Brown furnace gives a better heating surface than the ordinary form of corrugated furnace, the reason advanced being that the flame, in flowing through the furnace, is interrupted by impinging against the corrugations of the ordinary furnace, while the Brown furnace offers practically an unbroken cylindrical surface. This same difference also makes the Brown furnace one more easily fired, as it is the nearest approach to a plain furnace.

As stated, the object of the tests was to determine the constant to be allowed in the Board of Supervisors' formula for determining the thickness of any given furnace, *i. e.*, for determining "*C*" in the formula, $t = \frac{D \times P}{C}$, the expectation being that, even if *C* should not be found to exceed 15,000, the largest constant allowed at present for corrugated furnaces, at least such a constant would be allowed, and the furnace accepted, as to invite their manufacture in the United States in competition with other forms. To determine this constant, hydrostatic pressure was applied to the exteriors of the test furnaces until they collapsed, the furnaces being carefully trammed while under various pressures; at certain intervals the pressure was released, and the furnaces trammed to discover when the limit of elasticity had been reached or passed.

The furnaces tested were four in number, and were made of steel boiler plate of a nominal tensile strength of 62,000 pounds, as stated by the representative of the Brown Company.

The furnaces were so made that the ends extended beyond the outer casings to allow coupons to be cut off to be tested by the Board of Supervisors, the purpose being to show that no special quality of steel had been used for the particular furnaces undergoing test.

The normal dimensions of the furnaces were as follows, in the order of the tests:

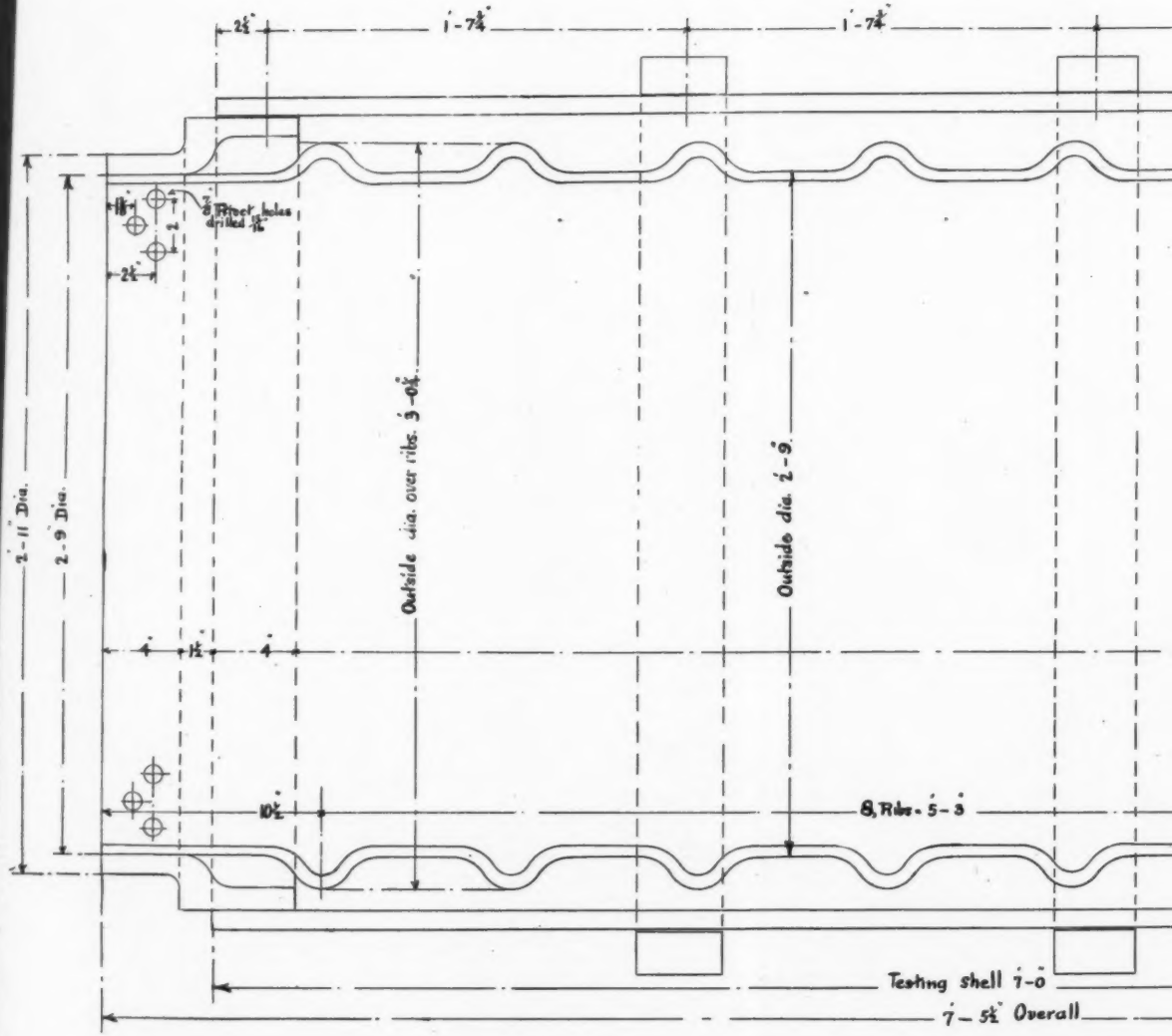
	Length.	Mean diameter.	Thickness.
Furnace No.	103, 6 feet 6½ inches,	31	$\frac{27}{64}$
	106, 6 feet 6¾ inches,	34	$\frac{26}{64}$
	105, 6 feet 6½ inches,	31	$\frac{27}{64}$
	104, 6 feet 6¾ inches,	34	$\frac{31}{64}$

The above figures are approximately correct, and are inserted here for easy reference; the actual dimensions shown by tramming and gauging are given in accompanying records of tests.

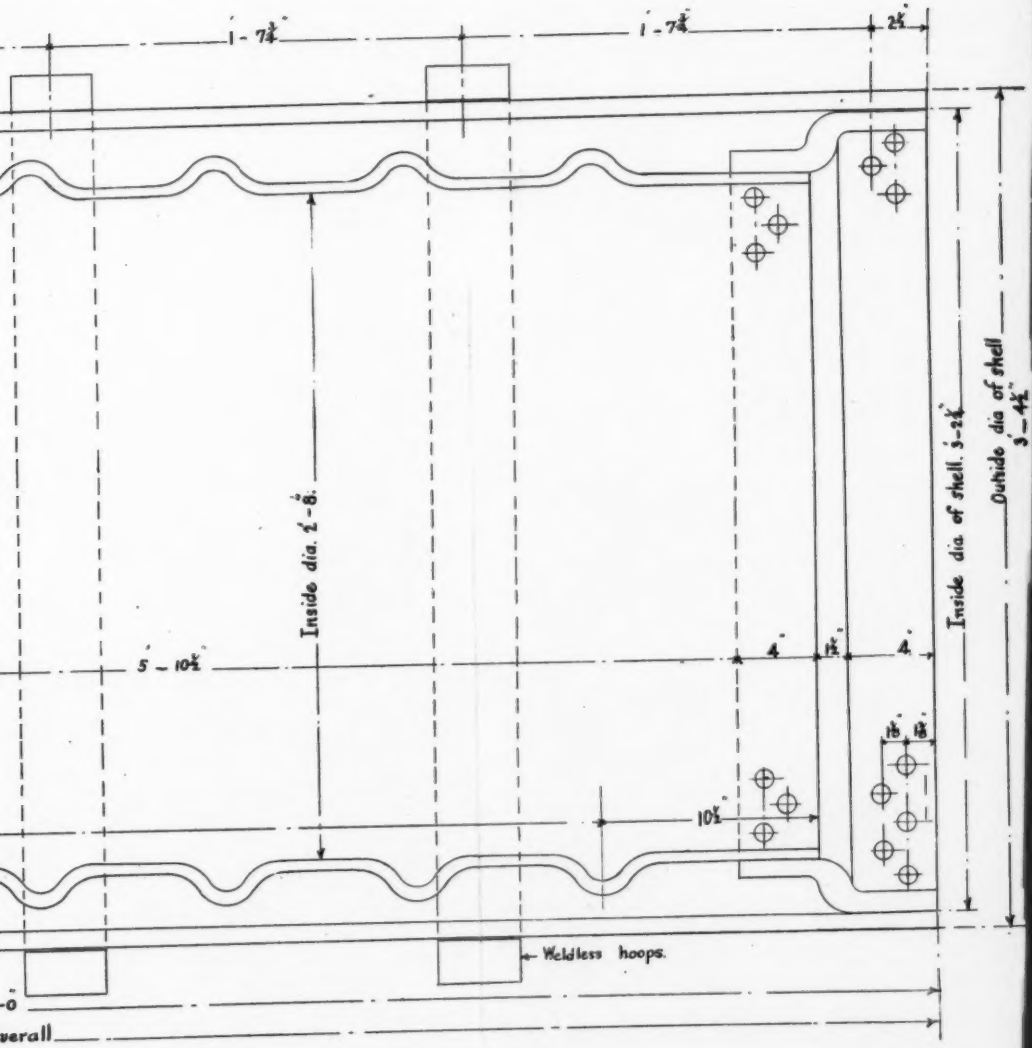
The accompanying sketches show the manner of preparing the furnaces for the tests. Each furnace was enclosed in a steel cylinder $1\frac{1}{16}$ inches in thickness, strengthened by three weldless steel bands $2\frac{1}{8}$ inches by $4\frac{1}{8}$ inches, and double riveted to separating bands of steel at each end. Hydrostatic pressure was applied and held at certain intervals of pressure from 400 pounds up, and the furnace carefully trammed horizontally and vertically to show deflections till a point was reached where it was considered dangerous to go into the furnace for tramming. At certain intervals also the pressure was released and the furnace trammed to note if it returned to its original dimensions and what approach had been made to the elastic limit.

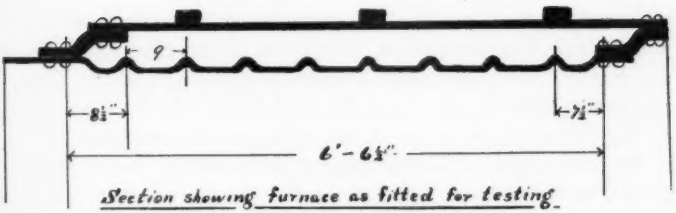
The first test was made on furnace No. 103, "outside ends." After the original dimensions had been carefully taken, the pressures were held at 400, 600 and 700 pounds and the furnace trammed at each of these pressures. The pressure was then released and the furnace again trammed, the pressure applied anew and the furnace trammed at 800 pounds, after which no tramming was done under pressure. The pressure was, however, released after reaching 950 pounds per square inch and the furnace trammed for distortion; after this pressure was applied

Cylinder as arranged for testing "Brownis improved Patent"

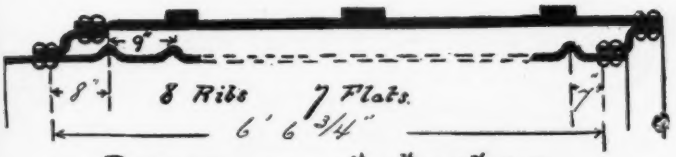


ved Patent Furnace. to destruction.

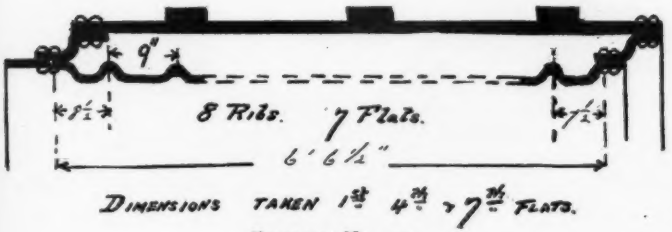




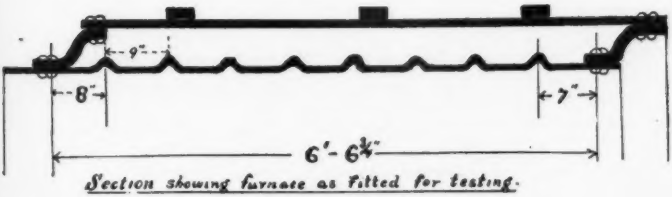
FURNACE NO. 103.



FURNACE NO. 106.



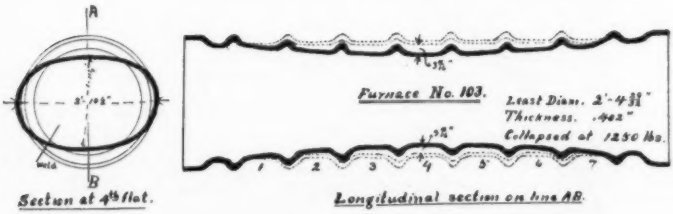
FURNACE NO. 105.



FURNACE NO. 104.

till collapse took place, this commencing at 1,250 pounds per square inch, the pressure of course not rising after the collapse had begun. The furnace came down slowly and regularly, assuming an oval form in the center, the ends being held by the riveting to the outside cylinder, as shown by accompanying sketch.

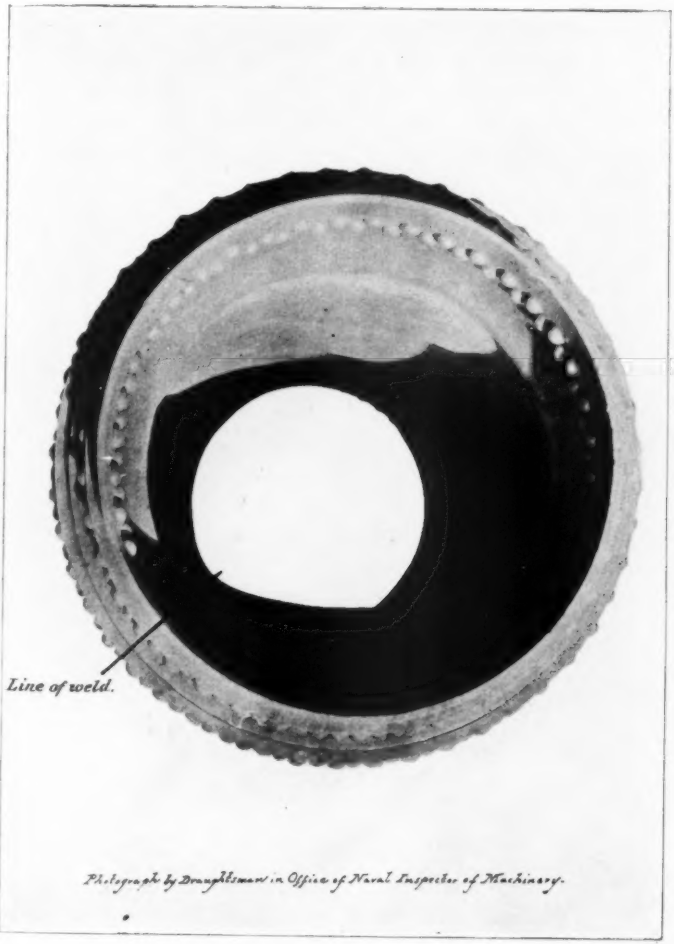
The dimensions at each tramming are shown in table appended. It will be noted that up to 800 pounds pressure per square inch



FURNACE No. 103.

Pressure in pounds per square inch.	First flat.				Fourth flat.				Seventh flat.				
	Vertical.		Horizontal.		Vertical.		Horizontal.		Vertical.		Horizontal.		
	ft.	*ins.*	*ft.*	*ins.*	*ft.*	*ins.*	*ft.*	*ins.*	*ft.*	*ins.*	*ft.*	*ins.*	
Original Diam.	2	5 5/32	2	5 1/8	2	4 31/32	2	4 31/32	2	4 29/32	2	4 29/32	*a.*
400	2	5 9/64	2	5 7/64	2	4 31/32	2	4 31/32	2	4 29/32	2	4 29/32	
600	2	5 1/8	2	5 7/64	2	4 31/32	2	4 31/32	2	4 29/32	2	4 29/32	
700	2	5 1/8	2	5 5/32	2	4 31/32	2	4 31/32	2	4 29/32	2	4 29/32	
0	2	5 9/64	2	5 1/8	2	4 31/32	2	4 31/32	2	4 29/32	2	4 29/32	*b.*
800	2	5 1/8	2	5 5/32	2	4 31/32	2	4 31/32	2	4 29/32	2	4 29/32	
950		...		...		...		...		...		...	*c.*
0	2	5 9/64	2	5 1/8	2	4 31/32	2	4 31/32	2	4 29/32	2	4 29/32	
1,250		...		...		...		...		...		...	*d.*

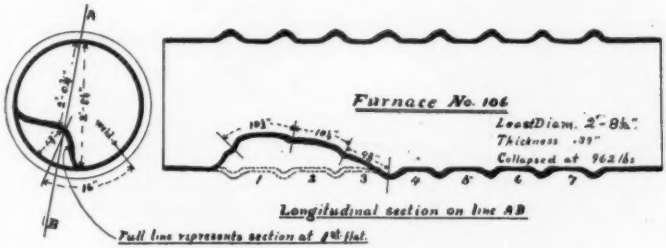
a. Before application of pressure.
b. Pressure released.
c. No measurements taken.
d. Collapse took place, see sketch.



FURNACE NO. 103.

FURNACE No. 106.

no dimensions had varied more than $\frac{1}{32}$, and that after the 950 pounds had been released the furnace returned to practically its original shape, there being a discrepancy of only $\frac{1}{64}$ of an inch and that at the end flats, the dimensions of the middle flat remaining the same as originally. After collapse the furnace was bored in three places and the thickness gauged, it being impossible to do this before the experiment, owing to the surrounding steel cylinder. The Naval Inspector found the thickness at the three points to be .404 inch, .418 inch and .402 inch. The measurements of the expert of the Board of Supervisors gave .405 inch, .420 inch and .376 inch, and he stated that as in his calculations he took the thickest part, .420 would be assumed as the thickness to be used in the formula for the calculation of *C*.

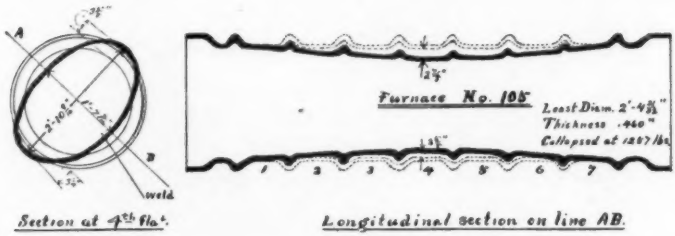


FURNACE No. 106.

Pressure in pounds per square inch.	First flat.				Fourth flat.				Seventh flat.				
	Vertical.		Horizontal.		Vertical.		Horizontal.		Vertical.		Horizontal.		
	ft.	*ins.*	*ft.*	*ins.*	*ft.*	*ins.*	*ft.*	*ins.*	*ft.*	*ins.*	*ft.*	*ins.*	
Original Diam.	2	$8\frac{23}{64}$	2	$8\frac{8}{32}$	2	$8\frac{1}{32}$	2	$8\frac{8}{32}$	2	$8\frac{8}{32}$	2	$8\frac{11}{64}$	
400	2	$8\frac{11}{32}$	2	$8\frac{8}{32}$	2	8	2	$8\frac{1}{32}$	2	$8\frac{8}{32}$	2	$8\frac{8}{32}$	
600		...		...		...		...		...		...	*a.*
0	2	$8\frac{11}{32}$	2	$8\frac{8}{32}$	2	$8\frac{1}{32}$	2	$8\frac{8}{32}$	2	$8\frac{8}{32}$	2	$8\frac{6}{32}$	
962		...		...		...		...		...		...	*b.*

a. No measurements taken.
b. Pocketed at second flat on the weld and produced collapse at that point.

The second furnace tested was No. 106, "inside ends." This being a furnace both of larger diameter and less thickness fewer data were taken. It will be noted from the table that after 600 pounds had been applied and released, this furnace, like the last, returned practically to its original shape, there being a discrepancy of but $\frac{1}{64}$ inch and that at only one of the end flats. This furnace collapsed at 962 pounds per square inch in a very different way from the first, as it pocked at the second flat. The dimensions of the pocket were about 24 inches in a circumferential direction by about 31 inches longitudinally by about $6\frac{3}{4}$ inches in depth. The thickness of this furnace by the Naval Inspector's gauging was .390 inch and .379 inch at the two places gauged, the Supervisor's final figure being .384 inch.

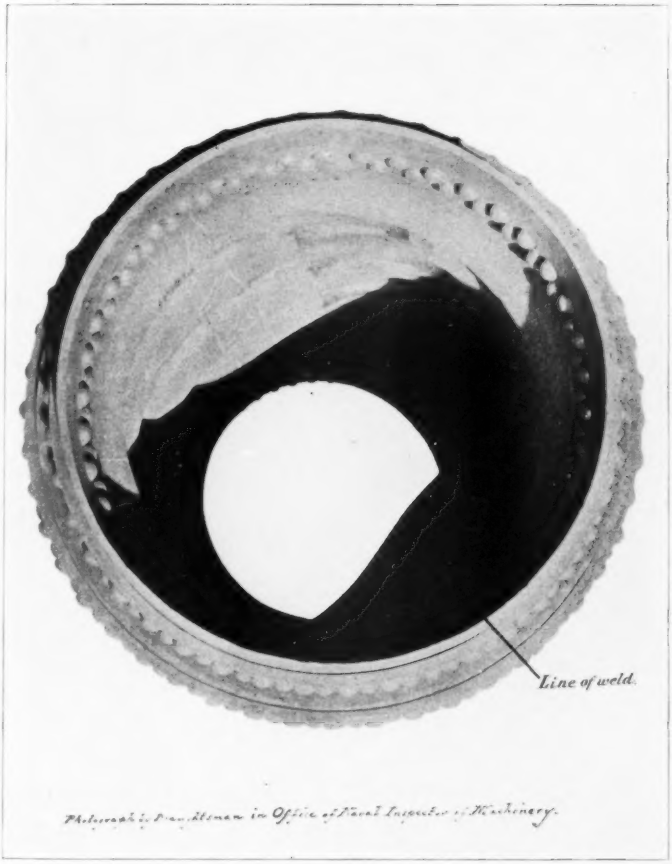


Section at 4th flat. Longitudinal section on line AB.

FURNACE No. 105.

Pressure in pounds per square inch.	First flat.				Fourth flat.				Seventh flat.				
	Vertical.		Horizontal.		Vertical.		Horizontal.		Vertical.		Horizontal.		
	ft.	*ins.*	*ft.*	*ins.*	*ft.*	*ins.*	*ft.*	*ins.*	*ft.*	*ins.*	*ft.*	*ins.*	
Original Diam.	2	$5\frac{3}{32}$	2	$5\frac{3}{32}$	2	5	2	$4\frac{11}{32}$	2	$5\frac{6}{32}$	2	$5\frac{7}{32}$	
500	2	$5\frac{3}{32}$	2	$5\frac{3}{32}$	2	$4\frac{11}{32}$	2	$4\frac{11}{32}$	2	$5\frac{11}{64}$	2	$5\frac{6}{32}$	
700	...		...		...		...		...		...		*a.*
0	2	$5\frac{3}{32}$	2	$5\frac{3}{32}$	2	$4\frac{43}{64}$	2	$4\frac{11}{32}$	2	$5\frac{6}{32}$	2	$5\frac{7}{32}$	
1,257	...		...		...		...		...		...		*b.*

a. No measurements taken.
b. Collapsed regularly from fourth flat each way to the ends—see sketches.

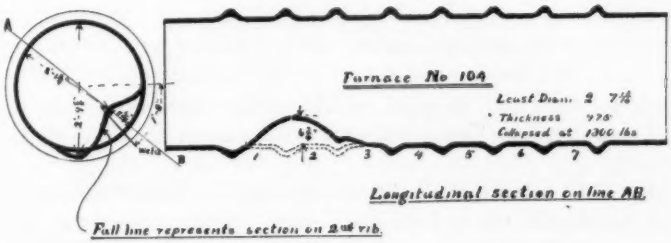


Photograph by Draughtsman in Office of Naval Inspector of Machinery.

FURNACE No. 105.

FURNACE No. 104.

The third furnace, No. 105, "outside ends," collapsed into an oval similar to the first, collapsing at 1,257 pounds. The thickness, as found by the Naval Inspector, was .461 inch, while the Supervisor's figures gave .460 inch. As in the preceding furnaces, it will be noted that the greatest distortion, after a pressure of 700 pounds had been applied and released, was $\frac{1}{64}$ inch, and that in one place on the middle flat.


Furnace No 104
Least Diam. 2 7¼
Thickness .775
Collapsed at 1300 lbs
Longitudinal section on line AB
Full line represents section on 2nd rib.

FURNACE No. 104.

Pressure in pounds per square inch.	First flat.				Fourth flat.				Seventh flat.				
	Vertical.		Horizontal.		Vertical.		Horizontal.		Vertical.		Horizontal.		
	ft.	*ins.*	*ft.*	*ins.*	*ft.*	*ins.*	*ft.*	*ins.*	*ft.*	*ins.*	*ft.*	*ins.*	
Original Diam.	2	$8\frac{3}{32}$	2	$8\frac{4}{32}$	2	$7\frac{7}{8}$	2	$7\frac{26}{32}$	2	$7\frac{24}{32}$	2	$7\frac{26}{32}$	
500	2	$8\frac{3}{32}$	2	$8\frac{3}{32}$	2	$7\frac{28}{32}$	2	$7\frac{28}{32}$	2	$7\frac{30}{32}$	2	$7\frac{27}{32}$	
700		...		...		...		...		...		...	*a.*
0	2	$8\frac{3}{32}$	2	$8\frac{4}{32}$	2	$7\frac{28}{32}$	2	$7\frac{28}{32}$	2	$7\frac{30}{32}$	2	$7\frac{27}{32}$	
1,300		...		...		...		...		...		...	*b.*

a. No measurements taken.
b. Collapsed and ruptured at 2d corrugation from end and in the weld, see sketch.

The fourth furnace tested, No. 104, "inside ends," showed a variation of $\frac{1}{32}$ inch in one place after a pressure of 700 pounds had been removed. It collapsed at 1,300 pounds per square inch, the collapse taking the nature of a pocket, as in the second

furnace. The collapse commenced at the weld at the second corrugation and reached the dimensions of about 30 inches in a circumferential direction by about 27 inches in a longitudinal direction by about 6¾ inches in depth. Up to this time no furnace had ruptured; this furnace, however, after the collapse, ruptured through the apex of the corrugation through the bottom of the pocket, the rupture commencing at the weld. It may be stated that in testing this furnace a plug blew out from the encasing cylinder while under 1,200 pounds pressure. The representative of the Brown Company offered the suggestion that the shock to the furnace material from the sudden release at this high pressure had an effect on the furnace weld which led to this rupture, but this conclusion would seem to be open to doubt.

It will be noted that all the furnaces were a trifle bell-mouthed, the diameter at one or both ends exceeding the diameter at the center flat, this difference varying from .15 inch in No. 106 to .275 inch in No. 104.

With this report are included photographs of sketches showing each furnace after collapse, as well as sketches of the furnaces themselves, the sketches being taken in planes through the greatest distortions. These sketches, with the accompanying tables of data, will clearly indicate the result of the tests.

To give a general idea of the results as indicating the strength of the furnaces, the formula used by the Board of Supervisors for determining the constant has been calculated in the various cases. The results, however, accurate as they may be with the figures given, are of doubtful value in the way of determining the strength of these furnaces as compared with others, as many other things are doubtless considered by the Board; and, not knowing the actual results in other cases for which constants have been allowed, as, for instance, the 15,000 for corrugated furnaces, it cannot now be determined what other considerations have been taken into account.

In these tests, however, taking the formula $t = \frac{P \times D}{C}$, or $C = \frac{P \times D}{t}$ in which

t = thickness of furnace in inches (greatest thickness by measurement at nominally thinnest portion of the furnace being taken, *i. e.*, at middle of flat);

D = mean diameter = inside diameter at flat + thickness of metal + 1⅝ inches (depth of corrugation);

P = working pressure (assumed, as stated by the expert of the Board of Supervisors, at one-sixth the collapsing pressure); we find the following results, taking the Board's figures for thickness and the least diameters:

Furnace No. 103,

$$D=31.01 \text{ ins.}; \quad P=\frac{1,250}{6}=208.3; \quad t=.420 \text{ in.}; \quad C=15,379.$$

Furnace No. 106,

$$D=34.06 \text{ ins.}; \quad P=\frac{962}{6}=160.3; \quad t=.384 \text{ in.}; \quad C=14,218.$$

Furnace No. 105,

$$D=31.07 \text{ ins.}; \quad P=\frac{1,257}{6}=209.5; \quad t=.460 \text{ in.}; \quad C=14,150.$$

Furnace No. 104,

$$D=33.95 \text{ ins.}; \quad P=\frac{1,300}{6}=216.7; \quad t=.478 \text{ in.}; \quad C=15,391.$$

Recapitulating:

Furnace No. 103, $C = 15,379$
Furnace No. 106, $C = 14,218$
Furnace No. 105, $C = 14,150$
Furnace No. 104, $C = 15,391$
$4)\overline{59,138}$
Average, $C =$ 14,784

As stated before, the constants thus calculated are intended to give only an approximation to the result of the tests. They are not to be regarded as official, nor as showing the rule by which the Board of Supervising Inspectors are guided in determining constants. It is to be remembered that the Board has conducted tests with other forms of corrugated furnaces, and that other factors must be considered in finally determining upon a

constant. It is also to be remembered that in arriving at these results the least diameter was used, and the thickness at the nominally thinnest part taken so as to be on the side of safety. Should the average of all the mean diameters be taken, as well as the mean thicknesses at the nominally thinnest part, the constant would be considerably increased. In fact, taking the average mean diameter, and the Naval Inspector's average figures for thickness, the resulting constant would be practically 15,000.

In furnaces Nos. 104 and 105, it is especially to be noted also that the collapse took place at the ends, where the diameters were largest. The middle portion, where the diameter was the smallest, was not practically affected. It would, therefore, seem not quite fair to use this least diameter in the formula in these cases. If the diameters at the point of collapse should be taken, they would increase the constant by from 60 to 80 beyond the figure above arrived at.

The Board of Supervising Inspectors of Steamboats, who conducted the tests, have made their report and assigned the value of 14,000 to the constant C. The Board therefore classify "Brown's Improved Corrugated Furnaces" under the head of "Ribbed Furnaces," of which the "Purves" furnace is the most familiar type. This furnace is manufactured by the same company, and for it the constant is the same, 14,000.

The following is an extract from the Minutes of the Board that conducted the tests:

The strength of Brown's corrugated flues, when used for furnaces or linings, corrugations not less than $1\frac{5}{8}$ inches deep, and not more than 9 inches from center to center, and provided that the plain parts at ends do not exceed 9 inches, and constructed of plates not less than $\frac{5}{16}$ inch thick, with practically true circles, shall be calculated from the following formula:

$$P = \frac{C \times T}{D}.$$

$C = 14{,}000$, a constant, ascertained by an actual test of this Board.

T = thickness in decimals of an inch, at center of second flat, to be ascertained by actual measurement through ¼-inch gas-pipe hole.

D = smallest outside diameter of flue in inches.

P = pressure of steam allowable.

Referring to the approximate value of C calculated from the tests by the Naval Inspector, it will be noticed that the latter uses for D the mean diameter of the furnace, while in the Supervising Inspector's formula, above quoted, D is the smallest outside diameter. Using this latter diameter in place of the mean diameter in the Naval Inspector's calculations for C, we obtain the following:

Furnace No. 103, $D = 29.805$ ins.
$t = .420$ in. $C = 14{,}780$

Furnace No. 106, $D = 32.819$ ins.
$t = .384$ in. $C = 13{,}750$

Furnace No. 105, $D = 29.905$ ins.
$t = .460$ in. $C = 13{,}620$

Furnace No. 104, $D = 32.803$ ins.
$t = .478$ in. $C = 14{,}870$

The mean of these four values is 14,256, which does not vary widely from the constant allowed by the Board of Supervisors.

Tensile tests made on specimens cut from the over length of the furnaces tested show the following average results: Tensile strength, 58,962; elongation, per cent., 27.6 in 6 inches; reduction in area, per cent., 63.8. These tests indicate that the material of the furnaces was of the character usually specified for such work.

ALLOYS.

INCREASED CONSUMPTION—IMPROVEMENT IN MANUFACTURE —THE QUESTION OF CONDENSER TUBES.

By Commander Warner B. Bayley, U. S. Navy, Member.

There has been a marked increase in the use of alloys during recent years. Particularly on board sea-going ships, where structural strength combined with non-corrosive qualities are essentials in the character of the machinery used, the increased use of alloys is very apparent. While it may be said in general of all structural material, that with the increased demand there has been a progressive improvement, this statement is particularly true of the alloys. The improvement as regards the quality of alloys and the uniformity of manufacture may be attributed more to the improved methods of manipulation of the constituents rather than to the character of the metal or to the change in proportion of the component parts.

So much, in fact, depends on the expert supervision and care exercised in the foundry where the brass and copper billets are cast, that some of the mills hold the men employed in this department responsible for the quality of the output. Should the metal, when it is tested after being cast, fail to come up to the standard requirements, the entire cost of the material is charged to their pay account. For this purpose, each billet cast in the foundry bears the workman's number who is responsible for the casting, by which means subsequent failure of the metal can be traced back to the responsible party. This custom insures the greatest care on the part of the workmen in mixing the metals.

Very recently, some of the great brass and copper mills of the Naugatuck Valley have adopted the custom of making frequent analytical tests during the operations of mixing and casting each heat, the chemical laboratory being kept in constant operation for that purpose. The marked improvement in foundry methods, due to the greater care on the part of the workmen, has resulted

in a partial solution, at least, of the well known difficulty of obtaining uniform results, as to mechanical qualities, with a given alloy.

Other causes which have contributed in a great measure to the improvement in the quality of the alloys are the very carefully drawn specifications, and rigid system of inspection adopted by the U. S. Navy Department for all copper, brass and bronze material entering so largely into the construction of the modern ship and its accessories. It has been my experience that manufacturers were at first disposed to complain of Government specifications as being unnecessarily rigid and difficult to comply with. I hear very little of this now; and, in fact, some mannfacturers claim that they are now in advance of Government specifications. In any event, it may be safely claimed that the quality of the material comprising the tin, zinc and copper alloys has greatly improved within a comparatively short time, due to improved methods in manipulation and manufacture. I have thought, therefore, that a brief description of some of the methods employed in the manufacture of two or three of the principal alloys may be of interest to the readers of the JOURNAL.

Copper and Brass Tubing.—The various manufacturers of copper and brass tubing employ radically different methods of manufacture, each claiming superiority in some particular of their special method, but all aiming at the same result, that is, to produce a seamless brass or copper tube perfectly true as to form, and concentric, of equal thickness in all parts, free from all surface defects, and that will comply with the required specifications as to the chemical qualities and strength of material.

In one establishment the brass and copper billets are cast solid. It being important that the metal should cool quickly, the billets are cast in iron molds, and precautions are taken to have the molds very clean, and well dressed with lard oil and graphite. Great care is also taken to have the temperature of the molten metal just right, neither too hot nor too cold, and the distribution of the stream governed and prevented from sticking to the sides of the mold. The copper billets, except the very large sizes, are cast in open molds, and then rolled hot to the required

diameter and length. No zinc is used in the copper billets, government specifications requiring 99.5 per cent. pure lake copper. The billet is then heated to a white heat (after being rough-turned to remove all surface imperfections), and in that state is passed through a set of three rolls. These rolls are set at an angle with each other and with the billet. The billet is hollowed at one end, and when it is introduced into the rolls a mandrel is centered in the hollow end. The motion of the rolls feeds the billet along, and at the same time forces it over the arbor or mandrel. After passing through this operation the billet has become a hollow cylinder. At the same time the peculiar motion of the rolls has given to the metal a decided twist of fiber. This twisting of the fiber, the manufacturers claim, adds to the strength of the finished tube and its power to resist internal pressure. After this operation the hollow cylinders are passed to the draw benches, where they are drawn cold through dies to the proper size and gauge of tube. Seamless copper tubes are now drawn to commercial lengths (12 feet) as large as 12 inches in diameter and No. 0 B.W.G. (.340 inch) in thickness. The above process, known as the Mannesmann, from the name of the inventor, was first introduced into Germany about twelve years ago. At first no mandrel was used, the solid billet being forced between the diagonally-acting rolls so proportioned and adjusted as progressively to reduce the diameter of the billet to a prescribed extent, while imparting to it a prescribed number of rotations. By this operation the billet was ruptured along the line of its axis and thereby made to assume a tubular shape. Many improvements have, from time to time, been introduced by the inventor, resulting finally in the process first described. The Benedict and Burnham Mfg. Co., of Waterbury, Conn., are the only manufacturers that use this process.

By the usual process followed by the great mills of Connecticut and Massachusetts the billets are cast hollow, and, after being thoroughly cleaned in a bath of sulphuric acid, the billet or shell is forced over an expander, the object being to develop any imperfections or flaws in the casting before it is sent to the draw benches for the final drawing. In the operation of drawing the

tube from the cast shell both care and skill are required in order not to strain the metal. Separate draw benches are used for the different sized tubes, and a dynamometer is used to measure the stress on the metal during the operation of drawing. By this means the metal is never strained beyond its safe tensile strength, and the danger of seams and cracks in the finished tube, which would possibly be invisible to surface inspection, thereby avoided.

At one of the largest brass and copper mills in Waterbury, Conn., instead of using a cast billet or shell, a sheet or disc of rolled metal is forced into the form of a cylinder by a punch and die. The subsequent drawing to a tube of given size is done in the usual manner. The advantage of this method is that a larger tube can be made, a specialty of this company being copper boilers.

Brazed tubing is still made in large quantities. It is principally used now, however, for plumbing and gas fixtures. None is used on board the ships of our Service. Brazed copper steam pipes as large as eight inches in diameter, strengthened by serving with closely laid copper wire wound under tension, are now being used to some extent abroad, I am informed.

In the manufacture of brass pipe, iron pipe size, the Government specifications require 60 to 70 per cent. pure copper and from 30 to 40 per cent. pure zinc. Considerable trouble has been experienced by the use of an inferior quality of western spelter (zinc) containing as high as 0.6 per cent. of lead and 0.3 per cent. of iron. An average of not more than 0.35 per cent. lead for iron pipe size and 0.2 per cent. lead for condenser tubes has been decided upon by the Bureau of Steam Engineering as a limit of this impurity. Some manufacturers strongly advocate putting in enough lead to insure 0.5 per cent. in the casting, instead of the 0.35 per cent., for iron pipe size, claiming that it will not impair the quality of the tube, while to reduce it 0.2 per cent. below that adds greatly to the cost of the material. It is my opinion, based upon many tests of this material, that for iron pipe size, when threading is be done, 0.4 to 0.5 per cent. of lead, and for condenser tube ferrules as high as 0.6 per cent. of lead, would be advantageous, as the material would work much better

and its physical qualities would not be reduced to an appreciable degree. I have seen experiments made with brass rod containing as high as 2 per cent. of lead, the only apparent effect being to reduce elongation slightly.

Naval Brass.—Experience with this material illustrates the truth of my remark as to the great improvement in the quality of alloys of very recent times, due to improved methods of manipulation. The results of sixty-six tests made by this office of naval brass give the following as an actual average:

Maximum strength per square inch, pounds, . .	61,895
Elastic limit per square inch, pounds, . . .	30,953
Reduction of area, per cent., ...	32.2
Elongation in 8 inches, per cent., ...	22.9
Elongation in 2 inches, per cent., ...	29

As these tests were quite uniform as to results, together with the fact that this material can be forged at a white heat as readily as steel, shows that it possesses the qualities of good open-hearth steel, with the additional advantage of being non-corrosive. The above results are in excess of the requirements of the Navy Department for naval brass as given in the specifications of 1901. Department specifications for naval brass require that it shall be composed of from 61 to 63 per cent. pure copper, 1 to 1½ per cent. tin, and the remainder zinc. Round bars ¾ inch in diameter and less to possess not less than 58,000 pounds ultimate tensile strength. Round bars over ¾ inch diameter not less than 50,000 pounds ultimate tensile strength, with not less than 10 per cent. elongation. The improvement in the quality of this alloy is apparent from the above figures. The results shown in the above table of tests made by this office, covering a period of eighteen months, would indicate that, with proper care and precaution in working, a fairly uniform and reliable material can be produced, having physical qualities that recommend it to designing engineers for use on board ship, for specific purposes, above all other material. Naval brass rods are now produced as large as 5 and 6 inches diameter, and in length as great as 12 feet.

The effect upon the physical properties of the alloy produced by the manipulation employed in reducing it to desired forms is very great, and is not well understood by designing engineers obliged to rely for information on the subject upon tests of such material as is furnished in the market. This is more particularly true of those alloys of copper with zinc and tin which are formed into the required shapes from the casting by the process of cold rolling or drawing. By this cold rolling or cold drawing process marked changes in the physical properties are produced, which, provided these operations are carried far enough, without the intervention of other processes (annealing), totally change the physical properties. The tensile strength and elastic limit are increased, and the percentage of elongation and contraction of area are reduced. The extent of these changes varies somewhat for given mixtures for the same amount of cold working. These changes, however, almost completely disappear when the piece is subjected to a temperature of about 80 per cent. of the melting point, corresponding, for most mixtures, to a red heat, and the physical properties become practically those of the original casting. As an illustration of the extent of these changes the following tests of a sample of naval brass, a bar of which was treated as described below, of an approximate composition of 63 per cent. copper, 36.15 per cent. zinc and .85 per cent. tin are given in the table below.

A sample bar of the above mixture was reduced to 1.249 inches diameter and carefully annealed. Three pieces were cut from it: the first was left as annealed, the second was drawn through a die to 1.224 inches diameter, and the third similarly drawn through a die to 1.063 inches diameter, a reduction respectively of 3.7 per cent. and 27.3 per cent. in area. All three samples were tested, with the results given in the table.

Sample No.	Tensile strength per square inch.	Elongation in 4 inches.	Contraction of area.	Yield point.
1	54,300	49.0 per ct.	43 per ct.	23,700 lbs.
2	57,100	43.4 per ct.	41 per ct.	33,700 lbs.
3	81,080	4.9 per ct.	36 per ct.	76,700 lbs.

The properties of this material are such that it can be given a very high tensile strength and elastic limit by cold drawing, but should it subsequently be heated in the operation of forging, these high values will be reduced to the result as shown in sample No. 1. I am indebted for the above table of tests, with remarks, to Mr. W. R. Webster, Jr., General Manager of the Bridgeport Brass Co., Bridgeport, Conn.

CONDENSER TUBES.

For the past two years, with few exceptions, all condenser tubes made for the Navy have been of the composition Cu, 70; Zn, 29; Sn, 1 (Admiralty mixture) not tinned, and, in the light of present knowledge on the subject, it is perhaps the best adapted to the purpose of all the alloys.

Tubes made of the mixtures Cu, 85, and Ni, 15 (Benedict Nickel) have recently been fitted in the main condensers of one of our ships, but I believe as yet no reports have been received which will serve to base any positive opinion upon in regard to the merits of the composition for this special purpose.

Until quite recently, the composition Cu, 60 and Zn, 40 (Muntz metal), tinned all over, was used almost exclusively in the Navy. The battleship *Wisconsin* is fitted with Muntz metal tubes, and, though only about two years commissioned, the tubes are giving out and will have to be renewed. Some experiments were recently made with this alloy, the results showing that the composition Cu, 60 and Zn, 40 is rapidly attacked by sea water. When a small percentage of iron, nickel or manganese, say .2 to .3 of 1 per cent. is present, the alloy resists the action of the sea water much better than when copper and zinc alone are used. It will be interesting to note the condition of the *Wisconsin's* tubes when removed—whether deterioration is due to disintegration, splitting or corrosion.

A writer on the subject recently attributed much of the trouble with condenser tubes in the Navy to the fact that the tubes are drawn too light, No. 18 B.W.G. being the standard thickness of tubes, claiming that the life of the metal was destroyed by drawing from No. 16 B.W.G. to No. 18 B.W.G., and giving this as

a reason for the better showing in the merchant service. This has not been the experience of this office, however, in testing the strength of tubes of all gauges. Tubes as light as No. 18 and No. 20 B.W.G., provided they are slightly annealed after the final drawing, possess all the qualities of ultimate strength, elongation and elastic limit as the heavier tubes.

Many theories have been advanced for the rapid deterioration of condenser tubes, other than that due to the alloy, electrolysis being one, and it has been suggested that the condensers should be completely insulated from the hull of the ship and from all piping. Unfortunately for this argument, however, the trouble existed quite as much in the days of wooden hulls as it does now. It is believed also by many that our condensers are too small for the work required of them. The fact that the ratio of total cooling surface to total heating surface in the Navy is about 1 to 1.5, whereas in the merchant service it is as high as 1 to .5, is given to prove this. It is a mistake, however, to suppose that the merchant service is exempt from this trouble. I have been told by the tube makers that it exists in the merchant service, though perhaps to a less extent than in the Navy. It is certain, however, that much, if not all, depends on the alloy, as well as the character of the workmanship of the tube maker. I believe we are getting a better condenser tube in the service to-day than ever before—due, as I have before stated, to improved methods,—and I hope to see a marked improvement in the life of the tube.

I believe, however, it would be worth while, as an experiment, to fit a condenser with tubes of the composition Cu, 85; Sn, 1 to 1½ and the balance pure zinc, or as pure as can be obtained in the market, the ratio of cooling to heating surface to be about 1 to .75, tubes to be ¾ inch diameter.

Extruded Metal.—By the process of extrusion, bars or rods of almost any particular cross section in brass or high tensile-strength bronze are produced, and so accurately that no machining is afterwards required. These special-shaped wrought rods, bars and angles are used in long lengths, or cut up into short sections, and supersede castings for many purposes.

The process consists of squeezing the heated metal through dies of almost any desired shape by hydraulic pressure (oftentimes as high as 60,000 pounds per square inch). The very high compression to which the semi-plastic material is thus subjected renders it perfectly homogeneous and free from possible casting defects. Its molecules are densely compressed, and the quality must necessarily be greatly improved. Extruded bars or rods consequently possess, in a very marked degree, those qualities which are essential for sound engineering work.

Various alloys may be used in this process, but not all of the alloys commonly rolled or cast. In addition to bars or rods of irregular cross section, all stock sizes of round, hexagon, square, rectangular, half-round, etc., are produced, suitable for forging into bolts or for all engineering purposes. Alloys used for this purpose are naval brass, Muntz metal, and other special bronzes suitable for forging. The alloys used for making angles, T bars and special shapes for marine work are approximately the same as naval brass, containing copper, tin and zinc in proper proportions to extrude into these shapes satisfactorily. All such alloys have high tensile strength and are particularly non-corrosive in their qualities. A recent test by this office of naval-brass extruded rods for bolt stock, to be used on the U. S. S. *Chattanooga*, resulted as follows:

Diameter,	.875
Reduced diameter,	.785
Reduction of area, per cent.,	19.4
Elastic limit per square inch,	41,600
Maximum strength per square inch,	63,200
Elongation in 8 inches, per cent.,	21

A test of an extruded angle of large size for the cruiser *Des Moines* resulted as follows:

Reduction of area, per cent.,	20
Elastic limit per square inch,	33,800
Maximum strength per square inch,	80,500
Elongation in 8 inches, per cent.,	18.1

The dimensions of the bars produced are limited by the weight of the billet adapted to the extrusion machine. Billets usually range in weight from 150 to 175 pounds, and rods are produced ranging in weight from ¼ of a pound per foot and about ⅜ inch in diameter to sections 10 to 12 pounds per foot and 4 to 5 inches in width. It will thus be understood that light sections may be had in long lengths, and heavy angles in lengths from 12 to 18 feet. The extrusion process of making rods for engineering work insures greater uniformity in the material than ever before possible, and for special purposes alloys may be produced having requisite tensile strength or elongation adapted for the work, even up to the strength of good quality steel, at the same time non-corrosive.

In addition to the extruded rods in common sizes and shapes, such as rounds, hexagons, squares, etc., T angles, I beams and bulb angles of any description are manufactured for use in hull construction of battleships, torpedo boats and yachts. Many yachts and launches have already been made with the frames entirely of extruded bronze bulb angles in place of steel. The material has also entered into the construction of self-closing compartment doors for ships, ammunition chain rollers, stanchions, and in other places where reliability, strength and non-corrosive qualities are required.

The hull of the new cup defender is of Tobin bronze, while the framing is of steel. As bulb angles and beams of sizes up to six-inch are made by the extrusion process, and as the metal possesses the strength and stiffness of mild steel, it would seem admirably adapted to this purpose.

The extrusion process, though new to this country, has been in use for some time in England and on the Continent. The Coe Brass Manufacturing Co., of Ansonia, Conn., are making this material in this country, and are now adding to their plant, for the purpose of manufacturing it on a more extensive scale.

Tobin Bronze.—There has been a marked increase in the use of this material on board ships of the Navy in very recent years for pump rods, bolts and nuts; and in cases where a stronger and more reliable material than it is possible to obtain with cast metal

is required, Tobin bronze is extensively used. It is now made in round and hexagonal bars as large as six inches in diameter, and in commercial lengths. The following are about the average of a number of tests of this material, made by this office:

Diameter of sample, inches,	1.25
Area, square inches,	1.227
Reduced diameter, inches,	.925
area, square inches,	.672
Reduction of area, per cent.,	45.2
Elastic limit, pounds,	53,000
per square inch, pounds,	43,200
Maximum strength, pounds,	75,000
per square inch, pounds,	61,200
Elongation in eight inches, per cent.,	36.63
by inches,	.34 .37 .23 .34 .70 .42 .32 .21

The Ansonia Brass & Copper Co., Ansonia, Conn., where this material is manufactured, have a very extensive plant, containing special machines for straightening and turning rods, so that piston rods up to six inches in diameter, and finished to size, are turned out.

The gross value of the brass and copper alloys produced in the State of Connecticut during the past year is upwards of sixty millions of dollars ($60,000,000), and, as a matter of comparison, the business generally has increased at the rate of 10 per cent. a year for the past decade. About 20,000 persons are employed in this industry in this State. One company alone in the Naugatuck Valley produced, approximately, fifteen million (15,000,000) pounds of copper tubing and brass rod during the past year.

In 1890 five firms engaged in the manufacture of copper and brass produced 5,000,000 pounds, and in 1900 eleven firms produced 29,500,000 pounds of rolled brass and copper.

THE NAVAL BOILER PROBLEM.

ITS IMPORTANCE IN DETERMINING NAVAL STRENGTH— ENDURANCE UNDER FORCED-DRAFT CONDITIONS— AN ANALYSIS OF EXTENDED SERIES OF TESTS OF HOHENSTEIN BOILER.

By Ensign John Halligan, Jr., U. S. Navy.

The water-tube boilers used in the several navies may, with few exceptions, be grouped in two classes: First, those with small bent tubes as commonly installed on torpedo craft; second, the large straight-tube type found on those naval vessels which are expected to do continuous steaming and to make foreign cruises.

The bent-tube types, by virtue of their elasticity of construction and assured circulation, combined with their relatively large combustion chambers, can be safely forced to a severe degree, provided the interiors of the tubes are kept clean, and the precaution is taken to prevent the accumulation of soot and scale between the tubes. The installation of this type of water-tube boiler is, in fact, the logical first solution of the effort to displace the Scotch boiler by one of lighter design. It was the inability of the Scotch design to withstand forcing, as well as the great weight of this boiler per horsepower when subjected to high pressures, that prepared a field for the introduction of the water-tube boiler.

In the effort to install large horsepowers in contracted spaces, it became necessary to provide for excessive heating surface per square foot of grate, and therefore in the bent-tube design the crowding of the tubes could not be prevented. The difficulty of cleaning the tubes under such condition, and the time and trouble required to locate and replace leaky tubes, conclusively showed that the installation of such types of boilers in naval vessels could only be justified by using them in torpedo craft or

in small fast scouts. In fact, the bent tubes have to be renewed so often, and therefore the reliability of the boiler is so uncertain, that most naval experts are now of the opinion that no type of bent-tube boiler should be installed in large vessels. Where regularity of steaming, economy and endurance are qualities of primary importance, it must be apparent that there is an advantage in, if not an absolute necessity for, the installation of the straight-tube design in battleships, cruisers and possibly gunboats.

The quality of endurance, however, must be the primary attribute in comparing the values of fire- and water-tube boilers. When the Scotch boiler was forced to a comparatively severe degree the collapsing of crown sheets was of frequent occurrence, and the blowing out of an occasional tube—due to corrosion, pitting or grooving—could be expected from every boiler whose tubes had been in use for three or four years. There were cases when tubes commenced to go in six months. It was these common mishaps that caused the engineering experts of all nations to seek for a substitute for the Scotch boiler which would be an improvement on that well-tried type.

The water-tube boilers that were first installed had comparatively small drums, thin tubes and light casings, and they had hardly been in use in the several navies for a few years before a reaction set in against the type in general. The several weaknesses of the water-tube boilers soon became manifest, and therefore in the latest designs of both the bent and the straight-tube type the drums are being made larger, the tubes thicker and the casings heavier. As a consequence, the weight of the water-tube boiler, particularly that of the straight-tube type, is more closely approaching that of the cylindrical or Scotch design.

In the report submitted by the British Admiralty to the House of Commons showing the relative cost of maintenance of the Scotch and the water-tube boilers some surprising facts were ascertained. The average cost of repairs to the fire-tubular boilers of fifty vessels, where there was an aggregate installation of 520,400 horsepower, was $202.33 per thousand horsepower per year. The cost of boiler repairs in thirty-one vessels, where there was

an installation of 400,000 horsepower of water-tube boilers, was $1,000.69 per thousand horsepower per year. The comparison was made for a period of five years.

Fortunately for the prestige and efficiency of our Navy, it has not been necessary for us to appoint boiler commissions to inquire as to the differences between the promises and the performances of a boiler selected as the approved type for the Navy. It is by reason of the sound judgment and professional acumen displayed by the Engineer-in-Chief of the Navy in his selection of types of water-tube boilers for installation on board ships in the American Navy that we have escaped a similar humiliating experience. It has been due to his progressive and yet conservative policy, founded upon experiment and upon experience, that we have had no tale of dismay and disaster similar to that experienced in some other navies.

THE BOILER OF TODAY.

The straight-tube type of water-tube boiler possesses special facilities for cleaning and for renewing tubes. Its construction is characterized by excellence of details both as to material and workmanship. Comparatively, high efficiency has been secured. Compared with the small bent-tube type, however, the straight-tube design is deficient as respects its ability to withstand more than a moderate degree of forcing. This weakness is either due to lack of elasticity of special parts, faulty construction, lack of circulation, or to a combination of these defects.

The limitations of the straight-tube type as regards its ability to be forced is recognized by the experts of every continental Navy. It is evidenced by the unanimous recommendation of a special commission recently appointed by the French Minister of Marine. This commission was composed of four superior officers of the Navy, who were directed to inquire particularly as to the type of boilers which should be installed on board three of the new battleships. After extended investigation this committee reported:

1st. That all the new cruisers and battleships should be supplied with boilers having straight tubes.

2d. That where straight tubes should be used, a greater combustion should not be demanded, during full-speed trials, than ten kilos per square meter of grate surface per hour. This is practically equivalent to a consumption of 22.7 pounds of coal per square foot of grate per hour.

It has only been a few years since a forced-draft pressure of an inch of water was regarded as the limit to which the Scotch boiler should be safely forced for a continuous period. It was, therefore, natural that naval engineers of ten to twenty years' experience with forced draft at this pressure should be quite satisfied with the design of water-tube boilers which could be safely subjected to conditions that could not be withstood by the steam generators of the Scotch type.

By reason of the fact that not only the bent-tube, but even the straight-tube type of boiler can now be subjected to three times an inch water pressure for continuous periods, it is going to be as difficult a matter to do away with the water-tube boilers as it was to install them. All navies will therefore devote time, energy and thought to effecting improvements in the design and in the construction of water-tube boilers rather than in looking for reasons why there should be retrogression to the Scotch type.

The fact also that the water-tube boiler not only can be repaired in less time than the Scotch design, but that in the reboilering of ships it will not be necessary to interfere with the structural arrangements of the vessels, constitutes a military advantage that must be given great weight in comparing the relative value of the two types.

THE BOILER OF TOMORROW.

Assuming, then, that the large straight-tube type of boiler has come to stay, and admitting the inability of this type to stand forcing to the extent to which the small bent-tube can be subjected, it seems logical that the next step in the development of the steam generator should be the adaptation of the straight-tube boiler to severe forced-draft conditions. This can only be effected by an extended, thorough and conscientious series of experiments

to determine more accurately the following properties of the boiler:—

1. The nature of the circulation of the water.
2. The character and extent of the baffling.
3. The best form of element.
4. The proper location and size of the downcast.
5. The simplest and most efficient manner of superheating.
6. The form and arrangement of the reservoirs or drums for containing for a brief period the liberated steam, and the provisions for liberation of the steam.

Other factors might also be considered, as follows:—

1. The size of combustion chambers.
2. Facilities for repair.
3. Ease of operating and overhauling the appurtenances.
4. Rapidity in getting up steam.

One of our leading shipbuilders has said that, at least in the merchant marine, the limit of speed under existing conditions has practically been attained. This expert maintains that the weight of reciprocating engines cannot be reduced, and that likewise the boiler weights under existing conditions are at a minimum. What more attractive, then, for the merchant marine than a reduction in weights by the development of a boiler that can be safely and economically operated at greater capacities than those commonly used?

In the naval service particularly there should be a still greater field for a straight water-tube boiler that could withstand high forced-draft pressures. It has been estimated that the maximum speed, and therefore the maximum boiler power of the naval vessel, is required only for a fraction of one per cent. of her steaming career. As coal consumption during that limited time may be absolutely disregarded, it is capacity and endurance that should be sought, rather than economy and efficiency under such extreme circumstances. It is economy at cruising speeds, combined with the ability quickly to secure the highest power that should be the controlling factors in boiler design for warships.

As it is a fact that in a boiler with a large combustion space

the loss in efficiency under forced-draft conditions is principally due to the increase in temperature of the escaping gases, the suggestion is made that, for the merchant marine at least, a system of heating the air requisite for combustion will be necessary to secure economical efficiency at the increased capacity.

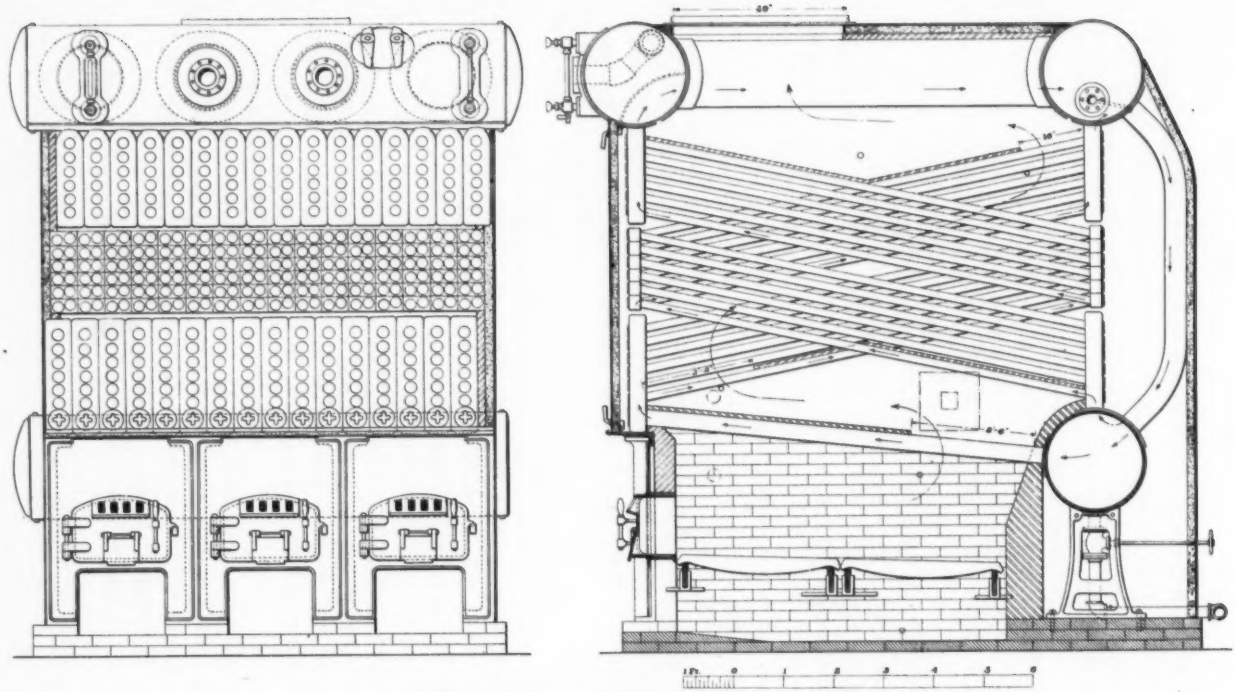
In an 18-knot battleship the boiler has been installed for the day of battle, and if maximum power could be secured at that critical time no consideration should be given to the question as to how much it cost to secure this capacity.

Under these conditions the ideal battleship installation should be so reduced that, allowing a margin of three or four boilers for cleaning, repairs, disablement, poor coal or inefficient stoking, the cruising speed should require all the remaining boilers worked under natural-draft conditions.

The following analysis of the boiler installation of the new *Maine* shows that could 30 horsepower be developed per square foot of grate, the boiler installation might be reduced one-half, provided endurance under forced-draft conditions could be assured. This vessel has twenty-four Niclausse boilers with 56.4 square feet of grate surface and 2,421 square feet of heating surface in each boiler.

Each of the boilers of the *Maine* should be capable of developing 670 horsepower when burning 24.62 pounds of coal per square foot of grate, and this ought to be done under favorable natural-draft conditions. Each boiler should develop 480 horsepower with easy firing, and when burning only 15 pounds of coal per square foot of grate. Under the latter condition eight of her boilers should give her a cruising speed of twelve knots even in a moderate sea. Could her boilers be forced to the extent of developing 28.4 horsepower per square foot of grate, ten of her boilers, or less than half the boiler-power installation, should develop the maximum designed power.

This practical and reasonable proposition has been stated in order the more graphically and the more forcibly to present the nature and the importance to the naval world of the extended series of tests that have been made by a Board of Naval Officers, using a Hohenstein cross-sectioned water-tube boiler. It will



THE HOHENSTEIN EXPERIMENTAL BOILER.

be seen later that the boiler capacity required for the *Maine*, with the proposed reduction in boiler installation, has repeatedly been exceeded under this experimental boiler.

THE HOHENSTEIN MARINE WATER-TUBE BOILER.

This boiler is undergoing what is probably the most extended series of official tests ever accorded a water-tube boiler. With the exception of an interval of a few months during which the transition from a coal-burning installation to an oil-burning plant was effected, the boiler has been subjected by the Hohenstein Boiler Board and the Liquid Fuel Board to continuous tests since April, 1901. The author of this article has assisted at every test conducted during the last six months. All the data has been recorded by employés of the Bureau of Steam Engineering or by persons connected with the Naval Service. Under the direction of the Liquid Fuel Board the writer has had general charge of the Navy crew during the time that the oil tests have been conducted. While there have been thirty-five official tests made with oil as fuel, there have been at least fifty additional preliminary trials that have been made by the several inventors to test their installations. There were seventeen official tests with coal as fuel, and many preliminary tests under various conditions of forced draft.

DESCRIPTION OF HOHENSTEIN BOILER.

The boiler is of 750 estimated horsepower, and was built to meet the requirements of the *Denver* class of cruisers as regards floor space, height and weight. It is admitted that the conditions as to boiler installation are as severe in the case of these cruisers as are likely to be met in any type of warship.

Drums.—There are six steam drums, forming a double hollow parallelopipedon. There is a front drum, 24 inches in diameter; a rear drum, 24 inches in diameter, and four connecting drums, each 16 inches in diameter. There is also a lower rear mud drum, 24 inches in diameter.

Tubes.—There are sixteen 4-inch tubes 7 feet long, 384 2-inch

tubes 9 feet long, and fifteen 5-inch downtake tubes which are connected to the rear steam drum and to the mud drum.

Heating and Grate Surface.—There are 2,130 square feet of heating surface and 50.14 square feet of grate surface. Ratio of heating surface to grate surface, 42.5 to 1.

Floor space.—9 feet wide, 10 feet 11¼ inches deep.

Height over all.—12 feet 6¾ inches.

Volumes.—Water at steaming level, cubic feet, . 142
Steam space, cubic feet, ... 50
Furnace above grate bars, cubic feet, . 121.14

Weights.—Boiler and fittings, excluding uptake and smoke pipe:

With water, pounds, ... 54,127
Without water, pounds, ... 46,668

Per square foot of heating surface at steaming level and at 275 pounds pressure:

With water, pounds, ... 25.4
Without water, pounds, ... 21.8

Water per square foot grate surface, pounds, . . 1,080

Ratios.—Area of grate to area of air spaces (average for all the tests with coal), 1 to .57.

Dimensions of smokestack.—

Height of stack above the grate, feet, . . . 70
Cross-section of smokestack, square feet, . . 8.73
Ratio of smoke pipe area to grate area, 1 to 5.75.

SPECIAL FEATURES IN DESIGN.

The most noteworthy features in the design of this boiler are those affecting its endurance under ordinary service as well as under extreme forced-draft conditions, viz:

1. Circulation.
2. Elasticity of construction.
3. Accessibility for the cleaning and the renewal of tubes.

The following features, although of less importance, are yet essential to an efficient installation on board warships:

1. A large body of water within the boiler and drum, thus affording a steadiness of water level.

2. A large steam liberating area, combined with a large steam space to insure dryness of steam.

3. A relatively large combustion space, the volume of which is 193 cubic feet, which permits the complete combustion of coal before reaching even the center of the furnace.

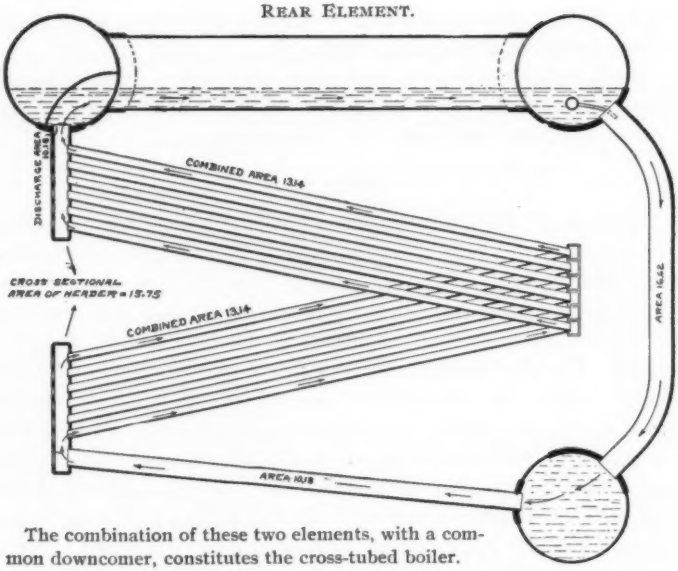
CIRCULATION.

Although declared unnecessary by many designers of water-tube boilers, this type of steam generator has a free area circulation throughout. The comparative areas of generating tubes and of downcomers is such that the carrying capacity of the latter is equal to the combined capacities of the generating tubes supplied. This has been accomplished without complexity of sizes, there being only two sizes of generating tubes—one of 4-inch and another of 2-inch. Incidentally it might be added that this principle of free-area circulation is probably secured in the small bent-tube boilers that have shown themselves capable of standing a high degree of forcing. In the boilers of the bent-tube class which are not provided with external downcomers of large area, an equitable proportion of generating tubes probably act as downcomers.

The kinetic energy of feed-pump discharge is conserved by nozzles in the feed line pointing into the downcomers. Then, through the downcomers the water travels at a comparatively cool temperature into a mud drum, whence it rises through a cross system of tube elements. This feature of feeding into the bottom of what corresponds really to a rear-header is termed by the designer the " Loop system."

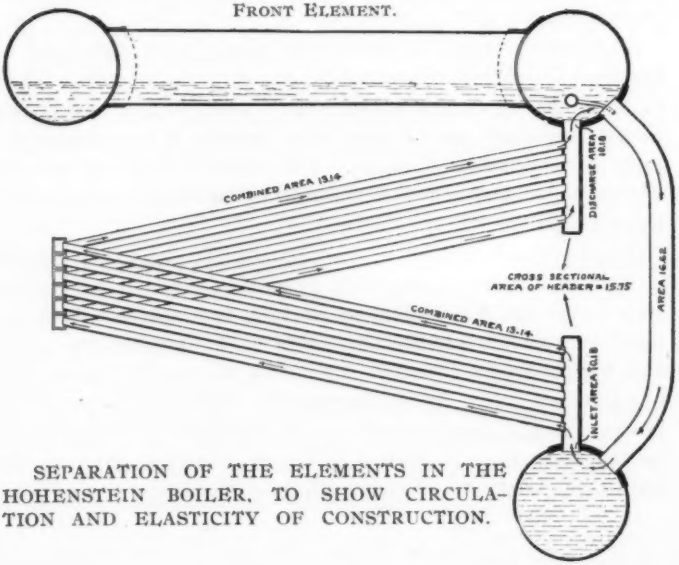
The numerous tests have demonstrated that there is an assured circulation of water under all the conditions to which the Hohenstein boiler has been subjected, despite the fact that there are obvious restrictions to the circulation in the length of the circuit and the change of direction of the flow due to the introduction of a junction box. As for the objection urged to the use of this junction box, it may be pertinent to state that in the Belleville design there are practically a half dozen junction boxes in the circuit comprised in a single element. If the contention of those

REAR ELEMENT.



The combination of these two elements, with a common downcomer, constitutes the cross-tubed boiler.

FRONT ELEMENT.



SEPARATION OF THE ELEMENTS IN THE HOHENSTEIN BOILER, TO SHOW CIRCULATION AND ELASTICITY OF CONSTRUCTION.

who believe in an assured circulation in the Belleville design can be maintained despite the use of several junction boxes, then valid objection cannot hold to the introduction of a single junction box in this design.

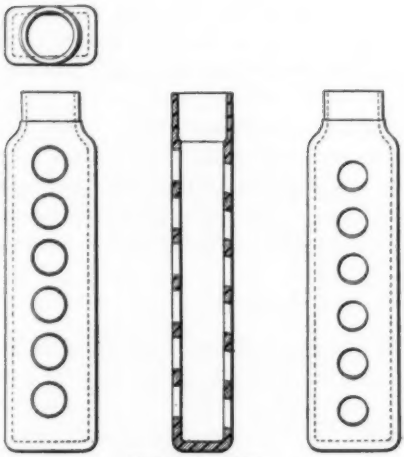
The results secured, rather than the broad claims made, are the foundation for the belief that there is merit in the free-area circulation and the "Loop system." It is therefore probable that this boiler or its development will yet play an important part in determining the approved type of naval boiler for the tomorrow.

ELASTICITY OF DESIGN.

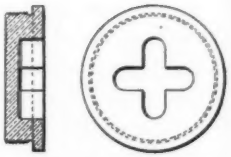
The tubes, instead of being expanded into rigid headers at both ends, are so arranged that at least one end of each tube is expanded into a junction box. This junction box is free to accommodate any irregularities in the expansion and in the contraction of the tubes expanded into it. This also relieves the drums of the severe strains of the rigid headers found in some designs. During a recent test the front casing was removed and fires were lighted under the cold boiler. It was observed that there was a displacement of one of the lower front junction boxes to an extent of about $\frac{1}{8}$ inch in the vertical plane.

ACCESSIBILITY OF TUBES FOR CLEANING AND RENEWAL.

The headers opposite the tube ends are closed by composition plugs. The plugs for the lowest row of tubes are $4\frac{1}{2}$ inches in diameter and have 8 threads per inch; all other plugs are $2\frac{3}{8}$ inches in diameter and have $11\frac{1}{2}$ threads per inch. The threads are lubricated with graphite. Some of the plugs were made with tapering threads and depend for tightness on these threads alone. It was thought that the relatively high coefficient of expansion of the composition would cause the plug to be tight under steam and easily removable when cold. It was found necessary, however, to cut out some of these plugs when it was desired to examine the tubes, leading to the belief that the composition when expanded had taken a permanent set, much as cast iron does under similar conditions.



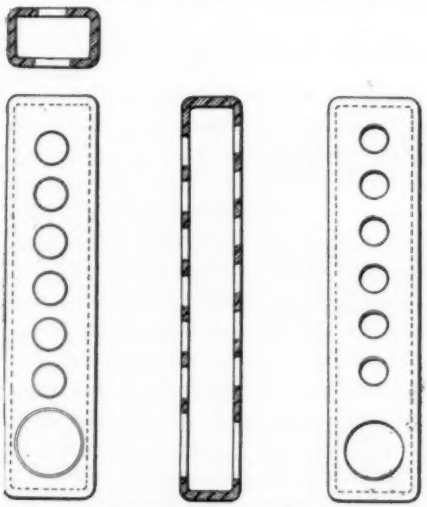
DRUM HEADER.



PLUG FOR FOUR-INCH TUBE.

PLUG FOR TWO-INCH TUBE.

JUNCTION BOX OF TWO-INCH TUBES.



LOWER FRONT HEADER.

DETAILS OF HEADERS, JUNCTION BOXES AND PLUGS.

The other plugs were packed under the flanges with Merwath gaskets, consisting of concentric copper and lead rings soldered together. The plugs secured in this way were more easily removed.

No zincs were used in the experimental boiler, neither are any of the parts galvanized. It seems likely that for service afloat with the likelihood of salt and of oil in the feed water, that it will be necessary to fit zinc rings over the tube ends.

The 4-inch tubes, being exposed to the greatest heat, should naturally be the most often examined. As these tubes are expanded into a mud drum at the rear end, this requires the removal of but one set of plugs, those screwed in at the front. The removal of these plugs, however, required the effort of two men on a six-foot lever. This naturally suggests the advisability of substituting handhole plates, at least in the case of the 4-inch tubes. All tubes can be withdrawn from the front.

There is room between the downcomers and the rear-headers to remove plugs and cut out the tubes, so that no space behind the rear casing is required for this purpose.

The cleaning of soot from between the tubes must be accomplished with a steam lance from the side, therefore hinged doors might be fitted to expedite this work. It must be recognized that the crossing of elements renders the cleaning more difficult in this type of boiler than in the case of other designs. However, this cleaning has been done under the experimental boiler for the past two years, and the possibility and the practicability of keeping soot and ashes off the tubes has been demonstrated.

STEADINESS OF WATER LEVEL.

This has been particularly commented upon by the water-tenders of the crew of the *Rodgers*, all of whom have had extended experience with torpedo-boat boilers. The water level has been so thoroughly under control that it has been customary in all the tests to bring the water in the glass to its original level at the end of each hour. No water cocks were fitted to the experimental boiler, and during many of the tests there has been but one gauge glass in use. These experiments have conclusively shown the necessity of finding a water glass that will be reliable

at 275 pounds steam pressure, and that it would be economy to pay a very high price for such a boiler fitting.

QUALITY OF STEAM.

The average quality of the steam for the thirty-one tests, the records of which have beed published, is .986. For the tests under forced draft where two or more inches of water pressure has been used, the average quality of the steam has been .982.

At no time during the tests have soda, salt or oil been introduced into the feed water. The following table shows the weight of water used in the boiler under varying conditions and the relative areas of water level.

Height of water in gauge.	Total weight of water.	Difference.	Area of water level.
	Pounds.	*Pounds.*	*sq. ft.*
0	8,588	...	...
1 inch	8,869	281	68.2
2 inches	9,235	366	72.2
3 inches	9,648	413	74.4
4 inches	10,033	385	75.7
5 inches	10,405	372	76.4

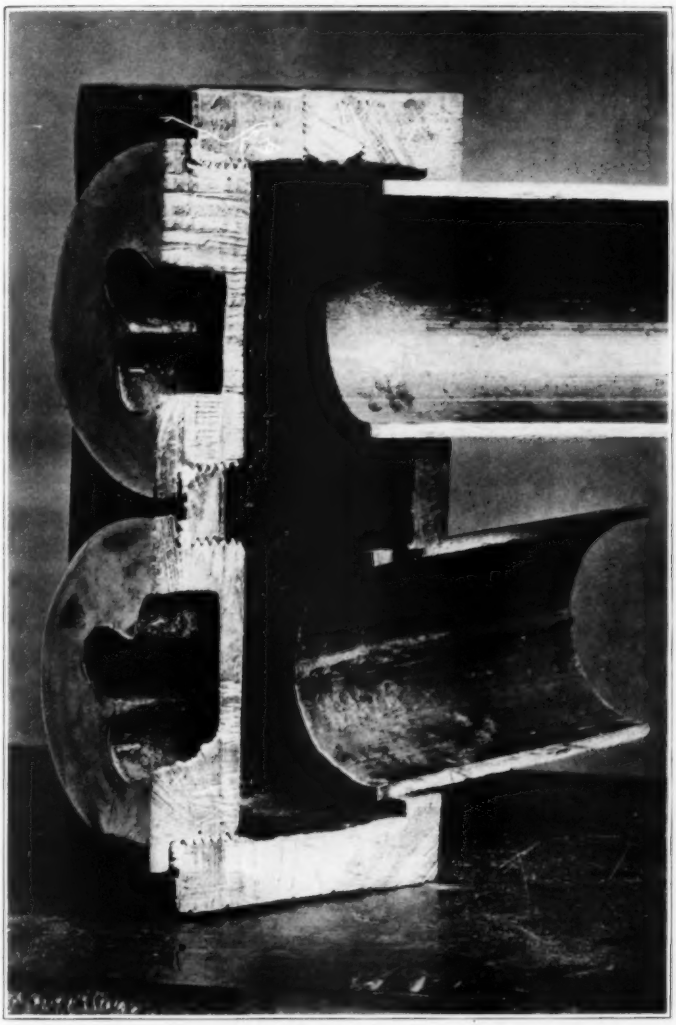
ENDURANCE OF THE BOILER.

The steaming hours of the boiler to February 14, 1903, inclusive, under the various degrees of draft during these tests, are shown in the following table:

.....	Natural draft.	Forced draft.						
		1″	1¼″	2″	2¼″	3″	3¼″	3½″
Hours	503	76	7	71	5	17½	4	4

In addition to this, according to data submitted by the Oil City Boiler Works, the boiler has steamed 170 hours during unofficial tests preliminary to the Government tests, as follows:

.....	Natural draft.	Forced draft.		
		1″	2″	3″
Hours	85	52	30	3



SECTIONAL VIEW OF JUNCTION BOX OF TWO-INCH TUBES.

While the official tests have continued for a total period of about 500 hours, it is but just to call attention to the fact that the boiler has actually been under steam at least twice that length of time. There has not been an inventor who has attached his appliance to the experimental boiler who has not used every pretext to make preliminary and unofficial tests. It has been the policy of the Liquid Fuel Board to encourage the making of these unofficial experiments upon the part of the several inventors, since valuable information has been secured by noting the failures as well as the successes of the various installations.

In analyzing the above tables it will be noticed that *the Hohenstein experimental boiler has sustained more forced draft exceeding one inch of water than all the water-tube boilers in the Service in other than torpedo vessels.* The steam pressure carried in all the tests has been 275 pounds.

Beyond the sweating of a calked seam in the end of a mud drum no leak has ever been detected in the boiler nor around the gaskets. The only repairs that have been made were to the linings of the casings and the renewal of gauge glasses.

The equivalent evaporation from and at 212 degrees Fahrenheit has ranged from 166 pounds to 709 pounds per square foot of grate surface per hour. This is practically an evaporation of 3.91 pounds to 16.7 pounds of water per square foot of heating surface per hour. The maximum evaporation was obtained by burning oil, and was restricted only by the capacity of the feed pump. Most of the tests have been with oil fuel, during which the lower tubes have frequently been exposed to a temperature of 2,200 degrees Fahrenheit.

CHARACTER OF THE FEED WATER.

For feed purposes the notoriously muddy water of the Potomac has been used. It must not be forgotten that the tests with this boiler have been carried on during every month of the year, and there are periods when the Potomac is probably as muddy as any river on the Atlantic coast. During the endurance trial of 116 hours the mud clogged the gauge glass to such an extent

that it became necessary towards the end of the run to blow down the glass at half-hourly intervals. Even during this test the efficiency of the boiler increased towards the end, clearly demonstrating that there had been sufficient circulation to prevent any deposit in the tubes.

No solvent of any description has been used in this boiler. From April, 1901, until January, 1903, a period of twenty-one months, there had been no scraping nor cleaning by mechanical means of the interior of the tubes. The boiler has been kept clean, however, but it was done by blowing down about a half glass of water at the end of each test. After about every sixth test the tubes are cleared by pumping river water through the boiler. On January 23d, 1903, the boiler was completely opened for examination; the 4-inch and some of the 2-inch tubes were scraped externally with wire brushes to determine the condition of the metal. The boiler was found to be in excellent condition throughout, with no evidence of burning nor warping of parts.

THE CONDITION OF THE TUBES.

The interiors of the tubes were found coated with a deposit about the thickness of and closely resembling cement paint. In the downcomers, where the circulation was the least rapid, there were found cakes of mud $\frac{1}{8}$ inch in thickness and several inches in diameter. There was about a bushel of deposit in the mud drum.

In the 4-inch tubes near the front headers were small lumps of deposit. When this deposit was removed there was no evidence of impairment of tubes either from corrosion or from overheating. For about 30 degrees of arc at the bottom of the tubes there was a channel free from deposit, which ought to be convincing circumstantial evidence as to the efficiency of the circulation. The condition of the tubes was considered so satisfactory that, beyond removing the small cakes of deposit from the 4-inch tubes and scraping out the accumulation in the mud drum, no cleaning was attempted. It is possible that if clear feed water were used occasionally, combined with the in-

troduction of some refined petroleum, this thin coating in the tubes would disappear.

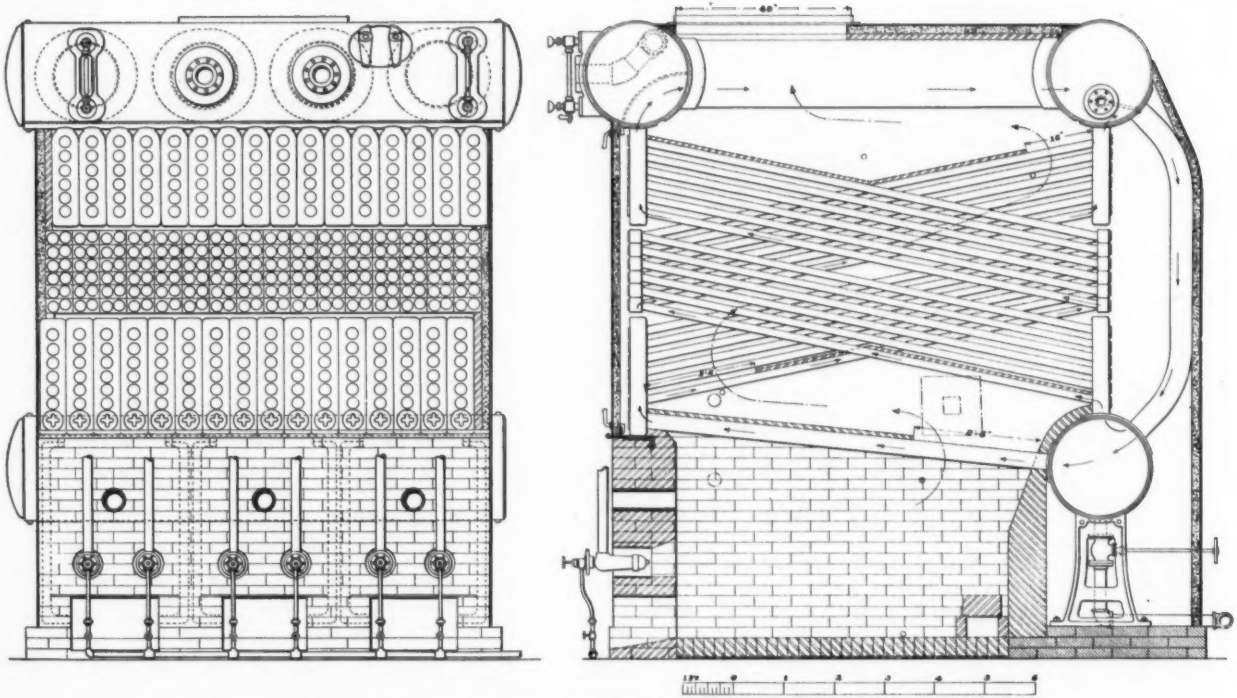
INCIDENTS OF ENDURANCE.

When the boiler was placed at the disposal of the Hohenstein Boiler Board in April, 1901, the designer requested that it be not spared nor nursed in any way. The following incidents in connection with the extended series of tests ought to show that this boiler is neither sensitive to undue heating of parts nor dangerous when there is irregular feed.

On January 11, 1902, while running a coal trial with 3-inch forced-draft pressure, the out-flowing tide exposed the end of the feed-suction pipe, making it impossible to supply feed-water to the boiler. The fires were hauled as rapidly as possible, but as the fan blower was outside the air-tight compartment, it was several minutes before the blower was stopped. In the meantime the heated tubes were exposed to the blast of atmospheric air, at a temperature of about 76 degrees Fahrenheit, blowing through the open furnace doors.

On five occasions during oil-burning trials the feed-water supply has failed, and the burners have been turned off, leaving the brick work in the furnace and combustion chambers white hot, with the water out of sight in the glass. On one of these occasions no water had been seen in the glass for a few minutes.

On October 25, 1902, while under 3-inch forced-draft oil-fuel trial, and evaporating 28,000 pounds of water per hour, the natural-draft evaporative capacity with oil as a fuel being about 12,000 pounds, there was a remarkable heating at the base of the stack. At the base of the stack a belt about 3 feet wide and extending about two-thirds the circumference reached a cherry-red heat. This heated belt would probably have extended entirely around the stack if it had not been for the fact that about a third of the belt was exposed to a strong breeze which was blowing at the time. In order that the test might not be discontinued, the boiler was operated for at least half an hour after it was feared that the stack might settle or fall. At the time the senior member of the Liquid Fuel Board regarded the condition of affairs as the severest test to which the boiler had been ex-



THE HOHENSTEIN EXPERIMENTAL BOILER AS ARRANGED FOR BURNING OIL.

posed. That the front drum as well as the upper rows of tubes were exposed to excessive temperatures at this time cannot be doubted.

On January 5, 1903, while running with 3 inches of forced draft, a nipple of the feed-line pressure gauge cracked. In order to continue this test, the feed pump was stopped with 8 inches of water in the glass and a new nipple fitted without reducing the rate of combustion for the hour. When the feed pump was started again the water had been out of sight for about two minutes. The evaporation per square foot of heating surface at this time was 10.33 pounds. That the water-tenders operating the plant remained in the closed fireroom and continued the 3-inch forced-draft test with water out of the glass and with repairs under way on the feed pump, is evidence of their confidence in the boiler.

RECORDS OF COAL AND OIL TRIALS.

The following tables (as to the performance of this boiler) are compiled from the annual report of the Bureau of Steam Engineering. They are submitted in support of the argument for the Boiler of Tomorrow.

The horsepower has been estimated on a basis of 16 pounds of water evaporated per hour.

TABLE I.—COAL TRIALS.

1	2	3	4	5	6	7	8	9	10	11
Test No.	H.P.	H.P. per square foot grate surface.	Coal per hour per sq. ft. grate surface.	Pounds coal per H.P.	Boiler efficiency.	Equiv. evap. per lb. of combustible from and at 212° F.	Difference between stack and fire-room temperatures.	Loss in economy due to 8.	Loss in economy due to incomplete combustion of C.	Ash-pit draft.
							° *Fahr.*	*per ct.*	*per ct.*	
11	511	10.19	18.5	1.82	73.4	11.77	396	...	...	Nat'l.
15	633	12.62	22.9	1.81	72.3	11.59	481	17.7	5.9	Nat'l.
12	732	14.59	27.8	1.91	73	11.69	475	...	...	1″
5	963	19.21	35.5	1.85	72.8	11.41	572	15.9	10.4	1″
13	1,347	26.86	53.4	1.99	67.2	10.79	631	...	...	2″
17	1,622	32.35	72.2	2.23	59.4	9.53	866	28.3	3.4	3″

The preceding table shows that under favorable conditions the boiler can develop about 1,800 horsepower, which is about 35.9 horsepower per square foot of grate surface within the limits of 2.5 pounds of coal per horsepower.

TABLE II.—OIL TRIALS.

1	2	3	4	5	6	7	8	9	10	11
Test No.	H.P.	H.P. per square foot grate surface.	——	Pounds oil per H.P.	Boiler efficiency.	Equiv. evap. per lb. oil from and at 212° F.	Difference between stack and fire-room temperatures.	Loss in economy due to 8.	Loss in economy due to incomplete combustion of C.	Fire-room draft.
							° *Fahr.*	*per. ct.*	*per. ct.*	
3	609	12.14	...	1.26	71.5	14.43	397	13.2	2.4	Nat'l.
5	732	14.59	...	1.28	70.4	14.22	445	14.4	0.7	Nat'l.
13	747	14.89	...	1.29	71.1	14.35	479	15.4	0.4	Nat'l.
7	1,090	21.74	...	1.39	65.8	13.29	627	15.1	1.2	Nat'l.
1	1,229	24.51	...	1.44	62.8	12.70	584	17.3	7.7	1¼″
2	1,515	30.21	...	1.51	60.3	12.18	657	20.1	6.4	2½″
4	1,846	36.81	...	1.55	58.1	11.73	746	24.2	1.7	3½″
8	1,938	38.65	...	1.70	53.4	10.77	902	28.1	1.2	3¾″

Table II shows that 2,000 horsepower may be developed from this boiler, using oil as a combustible. Assuming 1 pound of oil to be the equivalent in thermal efficiency of 1.5 pounds of coal, which ratio has been established by the Liquid Fuel Board in the conduct of their extended series of tests, this capacity will require an expenditure of 2.7 pounds of coal per horsepower.

Both tables are particularly instructive in showing the excessive loss in efficiency at the higher rates of combustion due to the high temperature of the escaping gases. These heat losses in the stack should show the necessity for heating the air requisite for combustion when attempting to secure maximum boiler power.

MODIFICATIONS IN DESIGN.

In a recent design of this boiler for installation in battleships and in armored cruisers the following changes are proposed:

1st. Sectional wrought-iron boxes, 4 inches by 6¼ inches, to be substituted for the mud drum.

2d. The front and the rear steam drums to be increased in diameter to 42 inches and 30 inches, respectively.

3d. Water walls to be provided in the furnace.

4th. The spacing of the front headers and the junction boxes to be such that it will be possible for a steam lance to be inserted, to permit of cleaning from the front of the outsides of tubes.

5th. The lower row of 4-inch tubes to be dropped 4 inches at the rear, to facilitate the cleaning of lower baffling.

MANY EXPERTS HAVE WITNESSED THESE TESTS.

Hundreds of persons have been invited to witness these tests. Scores of experts, representing naval, maritime, manufacturing and commercial interests, have spent hours at the experimental plant. It has been recognized that it has neither been desirable nor possible to withhold for any length of time data that others might have a special interest in securing. It is fair to say that no more complete and exhaustive boiler tests have ever been conducted under absolutely naval auspices. Realizing that the real test of a boiler must be at sea, the conditions during all the tests have been made to approximate sea conditions as closely as is possible on shore. They will stand for a long time as evidence of the intelligence, the thoroughness and the fairness of the Navy Department in the conduct of official tests of appliances relating to the naval service, under the cognizance of the Bureau of Steam Engineering.

THE MILITARY IMPORTANCE OF THE BOILER PROBLEM.

The boiler question grows in importance the more closely the subject is studied. The trend of naval thought in this direction may be evidenced by the following facts:

Over three years ago the British Admiralty appointed a Boiler Commission to investigate, among other subjects, the question of determining if an improved type of boiler could be found for the Royal Navy. This Commission has not hesitated to demand the employment of naval ships in commission for the collection of comparative data upon the subject.

TABLE SHOWING COMPARISON OF THE HOHENSTEIN WITH

Name of boiler.	Size.			Bulk.				Qual. of steam.		Circula	
	Estimated horsepower.	Grate area.	Total heating surface.	Weight of boiler in service, empty.	Weight of boiler in service with water at steaming level. Boiler hot.	Ratio of projected area to grate area.	Height over all.	Steam liberating area expressed as a percentage of total heating surface.	Volume of steam space.	Ratio of area of generating tubes to downcomers.	Length of generating tubes
		sq. ft.	*sq. ft.*	*Pounds.*	*Pounds.*		*ft. in.*	*Per cent.*	*cu. ft.*		
Hohenstein, "Experimental"..	750	50.14	2,130	46,568	54,127	1.97†	12 6¼	3.52	50	1.58	{108 129
Hohenstein, * "Battleship"..	1,333	93	3,990	85,386§	97,689§	1.84	13 9	3.73	177	2.01	{108 129
Babcock & Wilcox *Wyoming*..	600	50	2,200	‡	‡	1.86	11 7	1.36	33	7.57	{52.5 26
Babcock & Wilcox, *Cincinnati*..	1,000	63.3	2,480	53,400	62,640§	1.6	12 6	1.71	55	7.3	{48 24
Niclausse, *Nevada*.....	600	55	2,220	‡	‡	1.76	10 10¼ (over dome)	1.13	42	5.5	26
Niclausse, *Maine*.....	666.7	56.4	2,421	‡	‡	1.4	14 8 (over dome)	0.908	45	14.4	25.7
Yarrow, *Nashville*.....	...	25	1,000	14,938	18,748	2.32	7 10	1.9	18.5	...	33.5

* Data furnished by Oil City Boiler Works.
† No space required behind rear casing.
§ Estimated.
‡ Not obtainable.

THE STRAIGHT-TUBE BOILERS OF THE U. S. NAVAL SERVICE.**

Circulation.			Elasticity of construction.	Care and maintenance.	
Ratio of area of generating tubes to downcomers.	Length of generating tubes expressed in diameters.	Sum of angles in bends of generating tubes.	Provisions for expansion of tubes.	Facilities for cleaning and withdrawing tubes.	Provisions for cleaning outside of tubes.
		Deg.			
1.58	{ 108 / 129 }	405	At least one end of each tube is expanded into a junction box, free to move.	Unobstructed from front of boiler.	Steam lance from side (removing section of casing).
2.01	{ 108 / 129 }	405	do.	do.	Steam lance from front between headers. Also doors in side casing.
7.57	{ 52.5 / 26 }	240	None except the inherent give in the construction.	do.	Steam lance through dusting doors in side casing.
7.3	{ 48 / 24 }	240	do.	do.	do.
5.5	26	280	Ends free.....	do.	Steam lance from between headers from front.
14.4	25.75	280	do.	do.	do.
...	33.5	...	None.....	From inside of drums.	Steam lance, by removing casing.

** For much of the data in this table the author is indebted to Mr. E. N. Janson, Bureau Steam Engineering, Navy Department.

The Lords of the Admiralty have likewise employed the cruisers *Minerva* and *Hyacinth* during the past two years, for practically no other purpose than to test the endurance and the efficiency of the installation of Belleville boilers as compared with equal installations of Scotch boilers in ships of equal tonnage.

The German Admiralty is not only conducting comparative tests at Charlottenburg, but the commanders of the ships in commission have been specially directed to gather reliable data for the Berlin authorities as to the efficiency and the endurance of the leading forms of water-tube boilers.

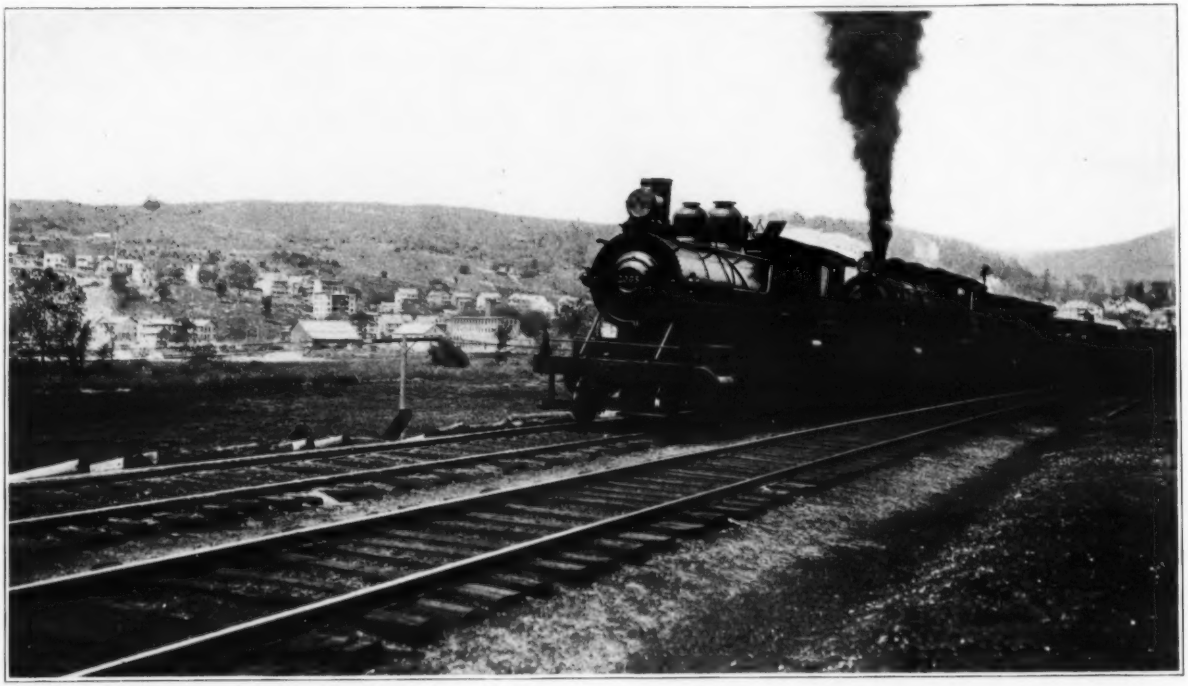
The splendid work of M. Bertin in his investigation of the efficiency of marine boilers, and in carrying out the earnest wishes of the French Minister of Marine to secure definite data in regard to the boiler problem, shows how seriously the French Admiralty regard the subject.

The interest of the U. S. Navy in the subject has been evidenced by the Bureau of Navigation permitting the continuous employment for nine months of a torpedo boat and its complement as auxiliaries to the work of the Hohenstein Boiler and Liquid Fuel Boards. The detail of this torpedo boat has been permitted despite the fact that there has been an exceedingly urgent demand for both the boat and its crew during the past year.

In all navies the corrosion of boiler tubes is going on at a rapid rate, very often in an incomprehensible manner. With impaired boilers ships can neither reach the battle line nor do extended cruising, and thus the actual strength of all navies is more apparent than real by reason of the weakness of the boilers.

It is an oft-repeated story which tells of some warship and even of an ocean greyhound hobbling into port with impaired boilers after an ocean voyage of less than a week.

Such facts must impress all naval experts with the realization of the proof that the naval problem of the hour may soon turn, if it has not already done so, in the direction of the problem of the boiler.



OIL AND COAL-BURNING LOCOMOTIVES DOUBLE-HEADING AT HOOSAC TUNNEL.

LIQUID FUEL.

By W. D. Hoffman, Associate.

The use of oil for fuel purposes in the marine service and on locomotives has received more attention in this country during the past three years than at any other period. It appears to be established in these two branches of motive power, wherever the conditions of supply are such that it may be obtained in quantities sufficient to meet the demand, and provided the prices are such that, taking the advantages to be obtained from oil fuel into consideration, it will be preferable to the other fuels in the market. It is not to be assumed that oil will displace coal, but for a locomotive or marine boiler it offers many important advantages which are not found in any other service.

These are, briefly, 1st, economy of space reserved for carrying fuel; 2d, ease in loading; 3d, reduction of labor in firing; 4th, saving of time in meeting a varying load on a boiler; 5th, absence of ashes and smoke; 6th, cleanliness of fire room; 7th, ability to force boiler to extreme duty in case of emergency.

It is the opinion of the writer that, with the constantly increasing demands for power and speed in both marine and railroad service, oil fuel will be resorted to on certain steamers and on certain trains where the service justifies its use, and, if limited as above, the supply will be sufficient to meet the demand.

The greatest obstacle to its use in the past has been the threatened exhausting of the supply by too extensive application, and many plants have been equipped only to find in a few months that the too urgent demand had increased the price beyond that of its equivalent in coal. The torpedo-boat service and the fast train, either freight or passenger, offer two fields which should always find sufficient supply at reasonable price, and in the latter case there are many railroads which make special conditions for a few

trains, in both freight and passenger service, whose fulfillment would certainly be greatly aided by the use of oil fuel.

It is not possible in the limits of this article to discuss fully these conditions, the intention being simply to give in a general way, some of the results from practical experience on locomotives, and compared with recent tests on marine boilers by the Fuel Oil Board.

Much has been done in an experimental way with oil as fuel for marine service during the past twenty-five years, but this work has been of but little use in practical service (outside of the Russian oil district). The reason is that in many cases oil was used as an auxiliary fuel with coal, while in others the burner was considered to be the principal feature in obtaining the results desired. In many cases the experimenters seem to have forgotten that when the oil is atomized perfectly the work of the burner is at an end, and the ignited oil gases must be treated the same as those from coal in a perfect state of combustion.

The attempts to generate an oil gas in the burner, or to superheat the atomizing agents will not increase the efficiency of the fuel, and in the former case will reduce evaporative duty.

The recent series of tests conducted by the Naval Fuel Oil Board under a Hohenstein boiler added a very valuable chapter to the work of establishing the use of oil as a fuel. The care taken in collecting and tabulating the records of these tests, and, better than all, the effort to conduct the tests on the exact lines of actual service, should commend it to everyone interested in oil fuel.

It has often been the writer's experience to be unable to record the results of work, owing to the necessity of meeting demands of service, and, therefore, I can appreciate the exhaustive data of the tests.

COMPOSITION OF OIL.

The analyses of oil used in the Hohenstein boiler tests seem to indicate that the oil used is what is known as "Texas Crude," and while there is quite a large supply of this oil at present in its crude state, it will doubtless be refined to a greater or less degree, and the heavier portions will form the supply for fuel purposes.

This has followed in the history of every oil field, and while the Texas oil, by reason of its low gravity and small percentage of lighter oils, offers the least attractive proposition the refiner has yet faced, it will be found that a paying percentage may be successfully refined. The presence of sulphur in this oil is not a disadvantage when used for boiler fuel, as actual experience has shown, and I do not think that at the temperatures of the marine or locomotive fire box the amount of sulphur in Texas oil will injure the sheets or flues, or otherwise prove deleterious.

Another point which has often been discussed is the gravity of the oil. At the present time the northern fuel oils vary from the distillate fuels, 34 degrees Baumé (0.8536 specific gravity), down to reduced fuel, 22 degrees Baumé (0.9210 specific gravity).

An average analysis of several samples of "reduced 22" resulted as follows:

Carbon, per cent., 87.72.
Hydrogen, per cent., 11.45.
Weight, per gallon, (231 cubic inches) 7.62 pounds.
B.T.U. per 1 pound, 19,800.

Average of several samples distillate fuel oil, 34.
Carbon, per cent., 86.19.
Hydrogen, per cent., 12.51.
Weight, per gallon, 7.11.
B.T.U., per gallon, 20,250.

As oil is sold by the gallon measurement, it will be noted that—

	B.T.U.
1 gallon, 22 gravity, contains, . . .	151,866
1 gallon, 34 gravity, contains, . . .	143,977
A gain, per gallon, 22 gravity, of . . .	7,889

I have generally found the heavier grades of fuel to be the most efficient for boiler firing, and if the oil is clean, and warmed sufficiently to bring it to the burner in a thoroughly limpid condition, the lower gravity oil will give the more economical results, as the increase in weight per gallon more than makes up for the loss in heat units per pound.

It has been claimed that the heavier oils are more liable to involve loss due to imperfect combustion and produce smoke, but here must be considered the main point in handling oil fuel, which is the construction of the furnace.

It is true that, after being broken by the atomizing agent, the heavier oil is slower in reaching a perfect stage of combustion than are the lighter grades, but with the proper admission of air, and with fire-brick lining of furnace arranged so as to maintain the high temperature as far as possible, there is no difficulty in maintaining a smokeless fire. The troubles from this source, I have often found, resulted from a cutting down of fire-box area and a restricti on of the flow of the partially consumed gases by defective arrangement of baffle walls and water-cooled surfaces.

It may be well to give special consideration to the burning of the heavy grades of reduced fuel oil, as these will, without doubt, form the bulk of the available supply. A very complete description of the Texas oil and oil field is given by Dr. W. B. Phillips, in Bulletin No. 1, University of Texas, July, 1901.

Table 1 following is very useful as showing the gravity and weight per gallon of the fuel oils.

TABLE 1.

Baumé scale.	Specific gravity.	Pounds per gallon.	Baumé scale.	Specific gravity.	Pounds per gallon.
15	0.9655	8.04	27	0.8917	7.43
16	0.9589	7.99	28	0.8860	7.38
17	0.9523	7.93	29	0.8805	7.34
18	0.9459	7.88	30	0.8750	7.29
19	0.9395	7.83	31	0.8695	7.24
20	0.9333	7.78	32	0.8641	7.20
21	0.9271	7.72	33	0.8588	7.15
22	0.9210	7.67	34	0.8536	7.11
23	0.9150	7.62	35	0.8484	7.07
24	0.9090	7.57	36	0.8433	7.03
25	0.9032	7.53	37	0.8383	6.98
26	0.8974	7.48			

To convert above weights per gallon to equivalent in imperial gallons multiply by 1.2.

Table 2 gives the evaporative duty of oil compared with that of coal.

TABLE 2.

Water evaporated per pound of coal.	Factor A.	Water evaporated per pound of coal.	Factor A.
3	.0714	8¼	.1965
3¼	.0770	8½	.2024
3½	.0833	8¾	.2084
3¾	.0893	9	.2143
4	.0952	9¼	.2203
4¼	.1012	9½	.2262
4½	.1071	9¾	.2322
4¾	.1130	10	.2381
5	.1190	10¼	.2441
5¼	.1250	10½	.2500
5½	.1309	10¾	.2560
5¾	.1369	11	.2620
6	.1428	11¼	.2680
6¼	.1488	11½	.2740
6½	.1527	11¾	.2800
6¾	.1607	12	.2860
7	.1666	12¼	.2920
7¼	.1726	12½	.2980
7½	.1785	12¾	.3040
7¾	.1845	13	.3100
8	.1905		

In the table—

A = factor of evaporative duty of coal = pounds of water evaporated per pound of coal ÷ gallons per barrel of oil (taken as 42).

B = factor of evaporative duty of oil = 2,240 (pounds in a ton) ÷ pounds of water evaporated per gallon of oil (being pounds evaporated per pound of oil × pounds of oil per gallon).

Hence,

C (which is wanted) = barrels of oil, 42 gallons each, to equal one ton (2,240 pounds) of coal = $A \times B$.

The pounds of water evaporated per pound of coal, and the pounds of water evaporated per pound of oil, also the weight of the oil per gallon being given, from them we find the values of A and B in table 2. Then

$$A \times B = C.$$

Thus, for example, suppose the evaporation from and at 212 degrees to be 8 pounds of water per pound of coal and 15 pounds of water per pound of oil. Then if the oil weigh $7\frac{1}{2}$ pounds per gallon, how many barrels (C) of oil will equal one ton of coal?

Factor $A = .1905$ is found opposite No. 8 in the first column.

Factor $B = 19.91$ is found in the line headed No. 15 and in the column headed $7\frac{1}{2}$ pounds per gallon. Then $(A = .1905) \times (B = 19.91) = C = 3.79$ barrels of oil equivalent to 2,240 pounds, or one ton of coal.

To convert into gallons, multiply by 42.

Water evap. per lb. of oil.	Factor B.				
	7 lbs. per gallon.	$7\frac{1}{4}$ lbs. per gallon.	$7\frac{1}{2}$ lbs. per gallon.	$7\frac{3}{4}$ lbs. per gallon.	8 lbs. per gallon.
12	26.66	25.74	24.88	24.08	23.33
$12\frac{1}{4}$	26.12	25.22	24.38	23.59	22.85
$12\frac{1}{2}$	25.6	24.71	23.89	23.12	22.40
$12\frac{3}{4}$	25.09	24.23	23.42	22.66	21.96
13	24.60	23.76	22.97	22.13	21.56
$13\frac{1}{4}$	24.15	23.31	22.54	21.81	21.13
$13\frac{1}{2}$	23.70	22.88	22.13	21.41	20.74
$13\frac{3}{4}$	23.27	22.46	21.72	21.04	20.36
14	22.85	22.19	21.33	20.65	20
$14\frac{1}{4}$	22.45	21.67	20.95	20.28	19.65
$14\frac{1}{2}$	21.97	21.30	20.60	19.93	19.31
$14\frac{3}{4}$	21.69	20.97	20.25	19.50	18.97
15	21.33	20.60	19.91	19.27	18.66

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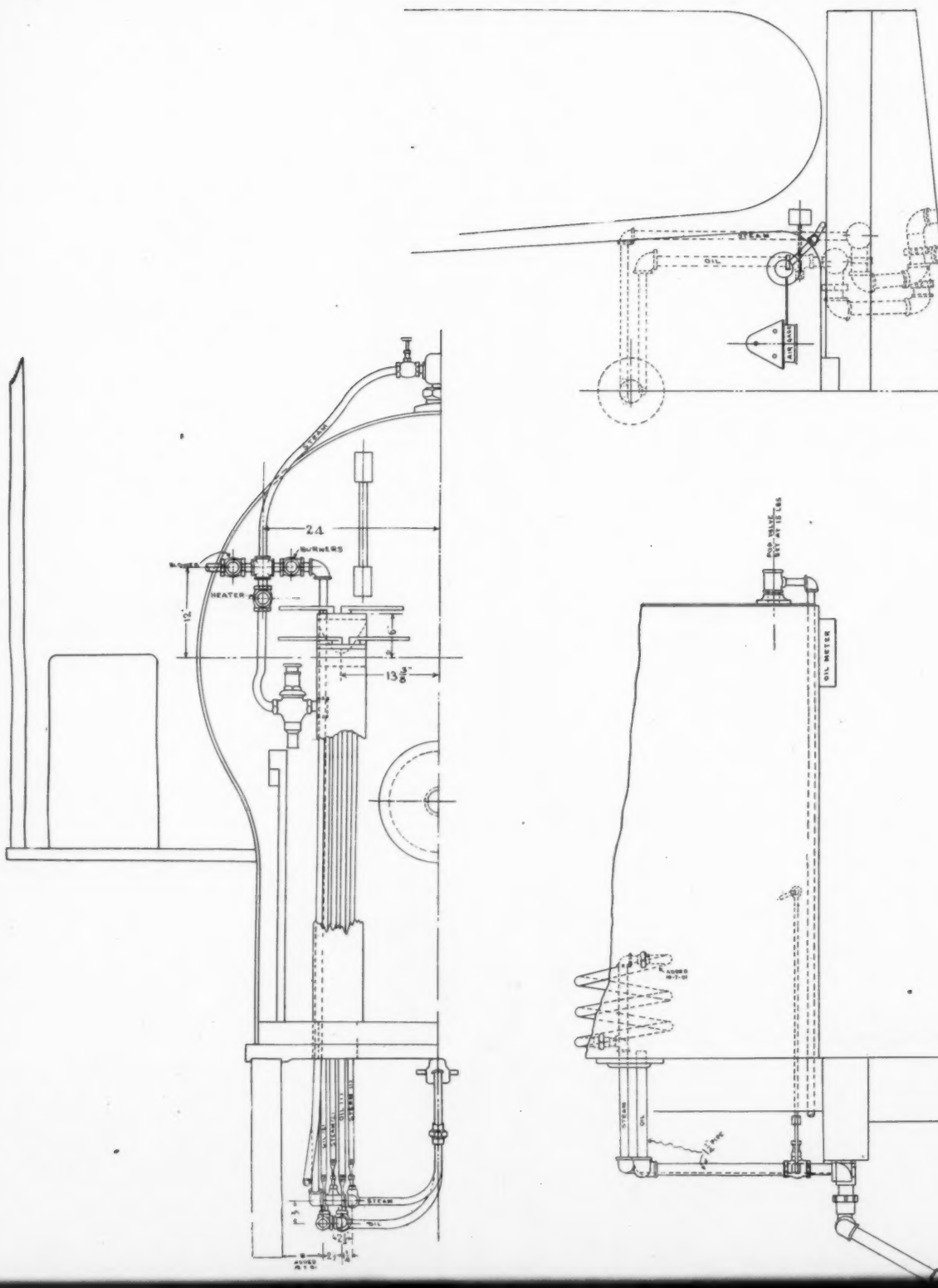
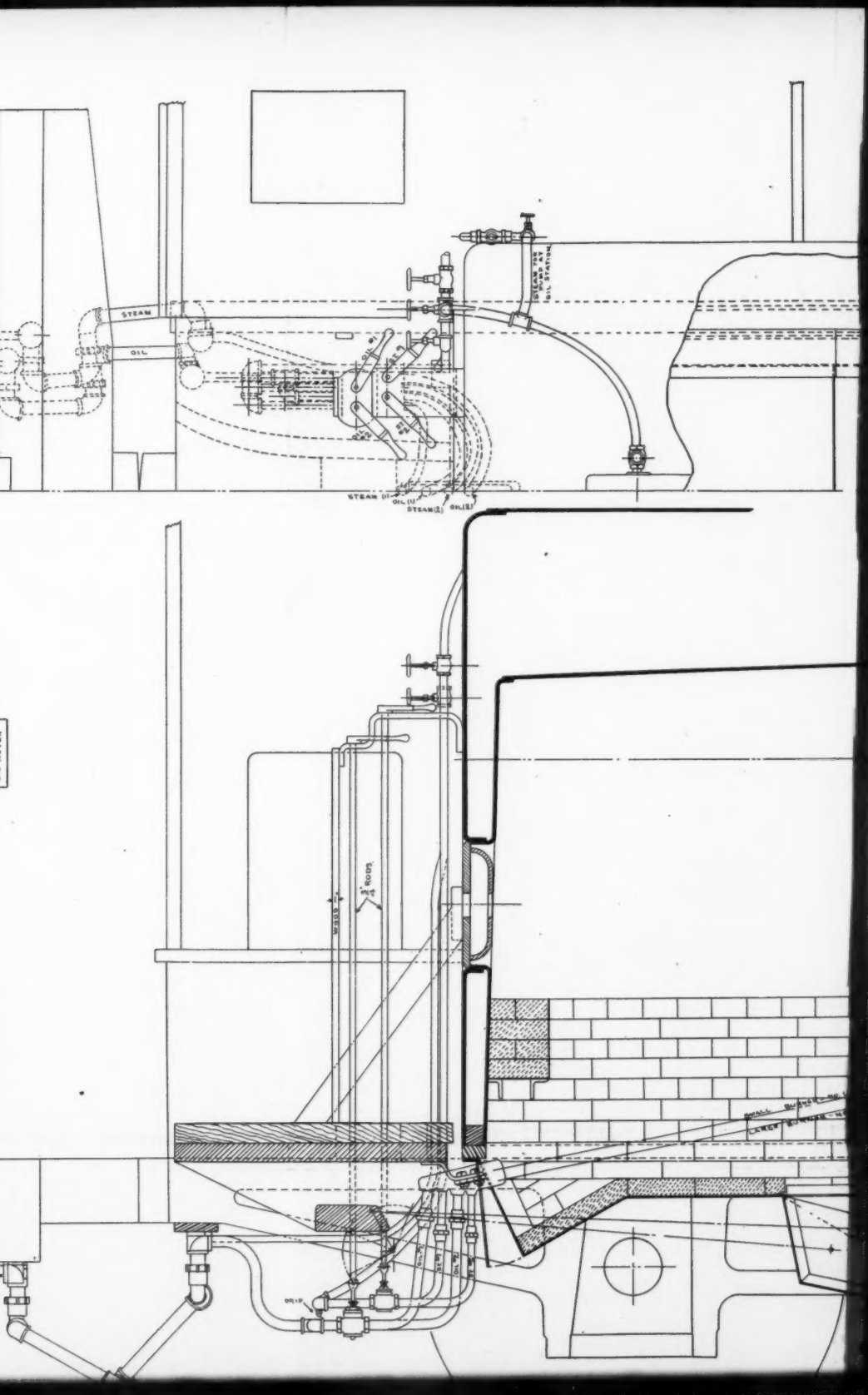
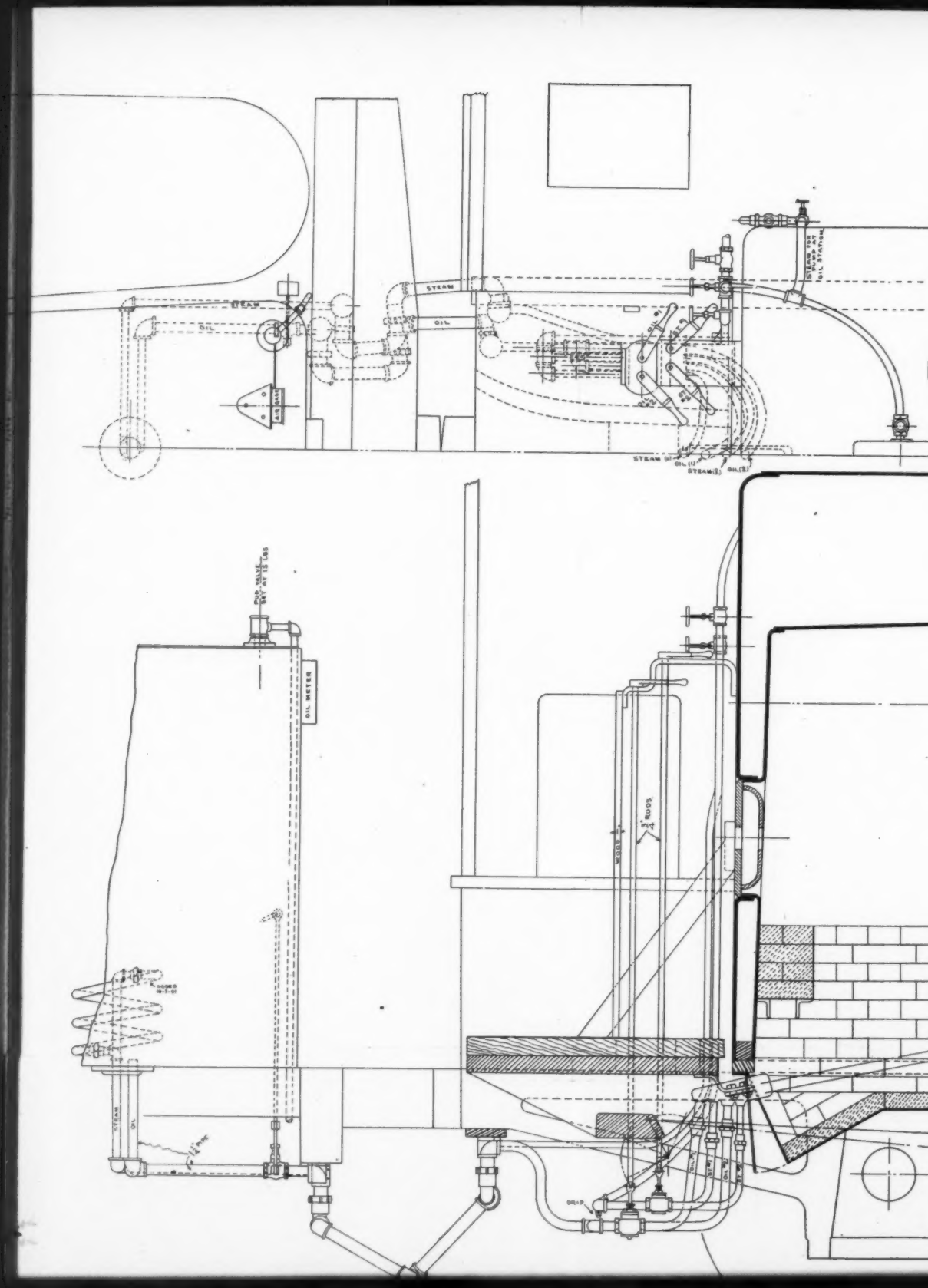

STEAM
OIL
AIR VALVE
STEAM
24
BURNERS
HEATER
12"
13 3/8"
POP VALVE SET AT 15 LBS
OIL METER
STEAM
OIL
12" PIPE
STEAM
OIL


STEAM
OIL
STEAM (1)
OIL (1)
STEAM (2)
OIL (2)
STEAM
DRIP


STEAM
OIL
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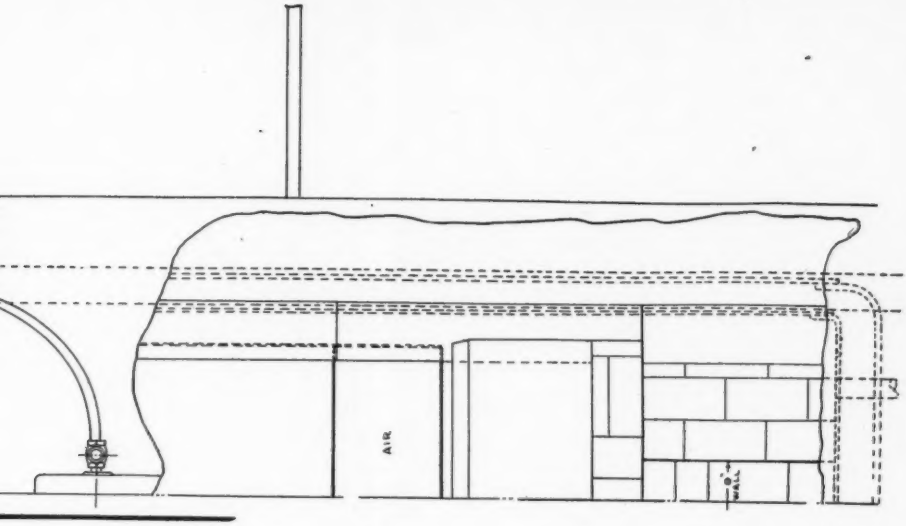
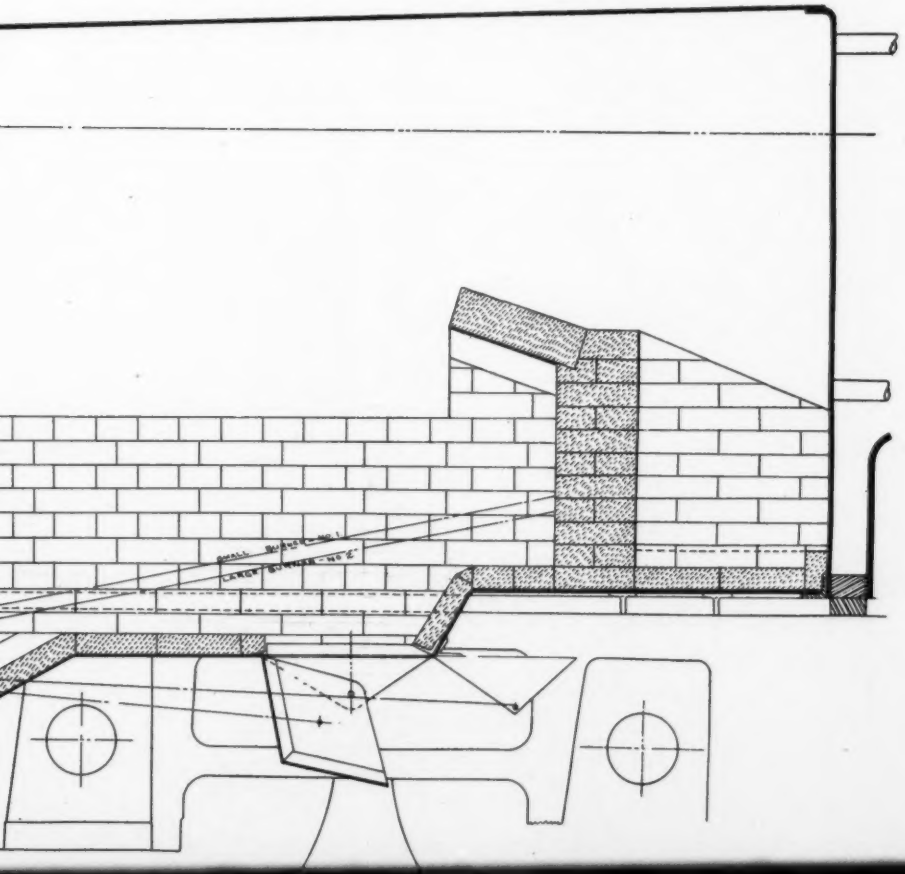
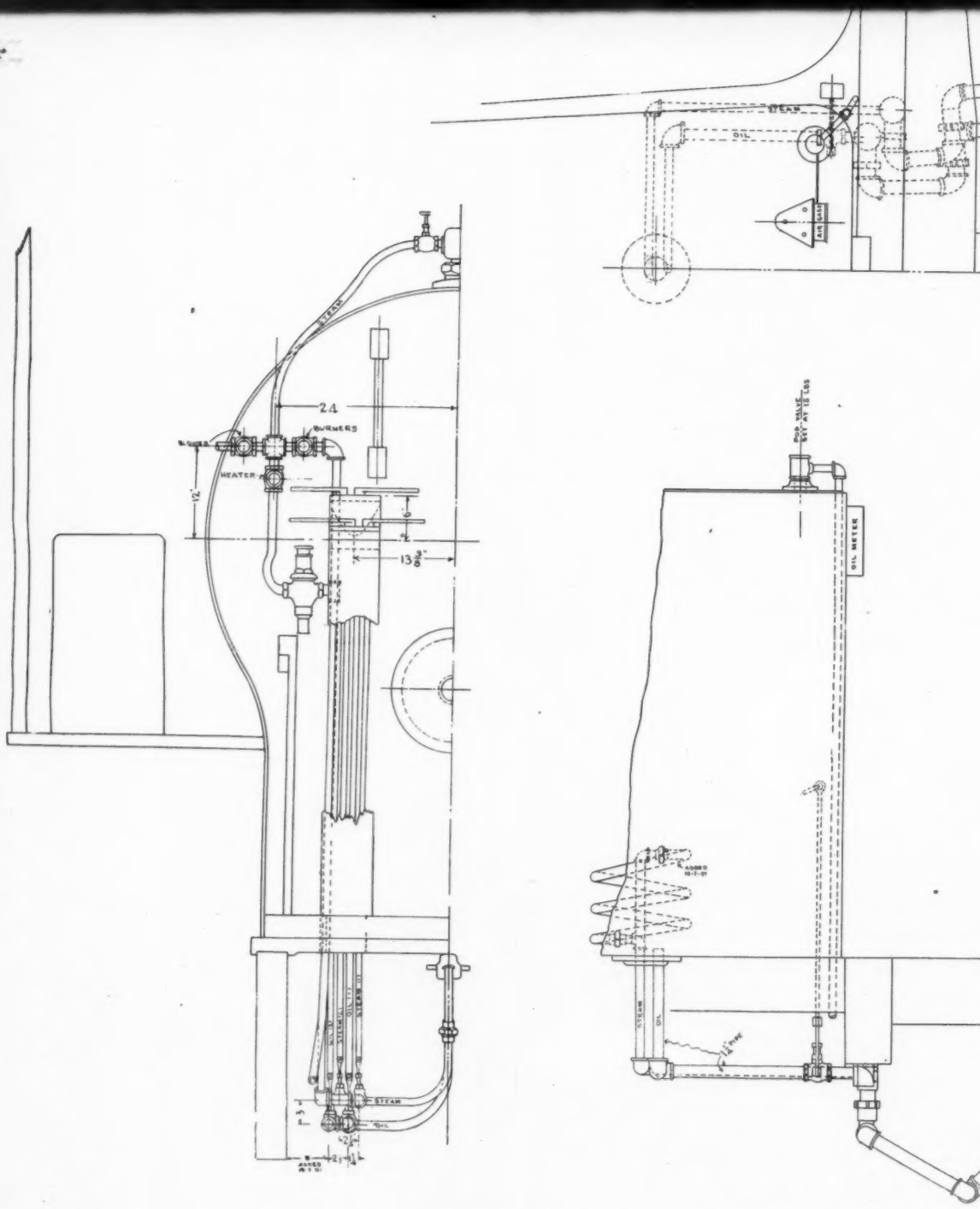
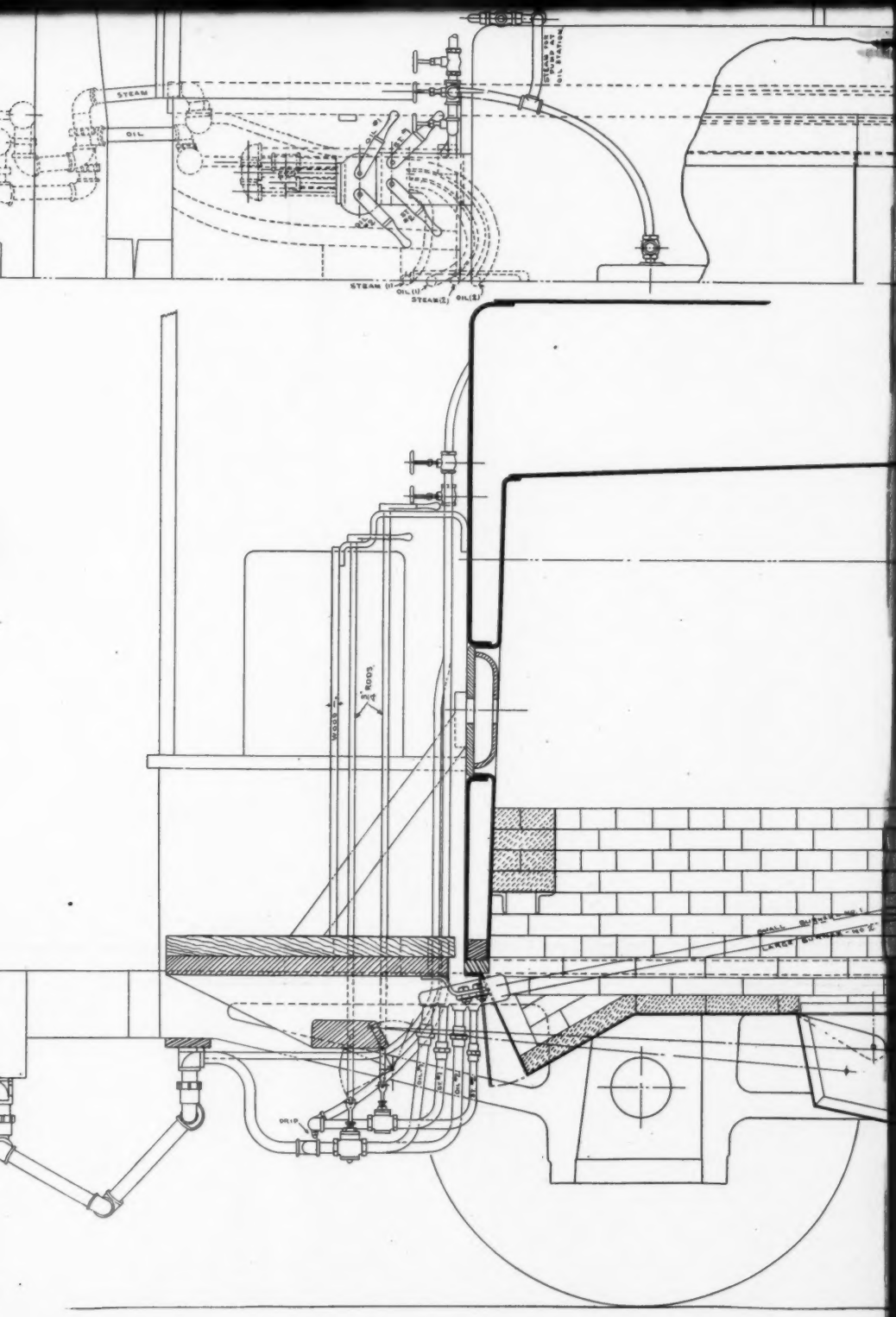
STEAM (2)
OIL (1)
STEAM (1)
OIL (2)
OIL METER
STEAM
OIL
DRIP


AIR



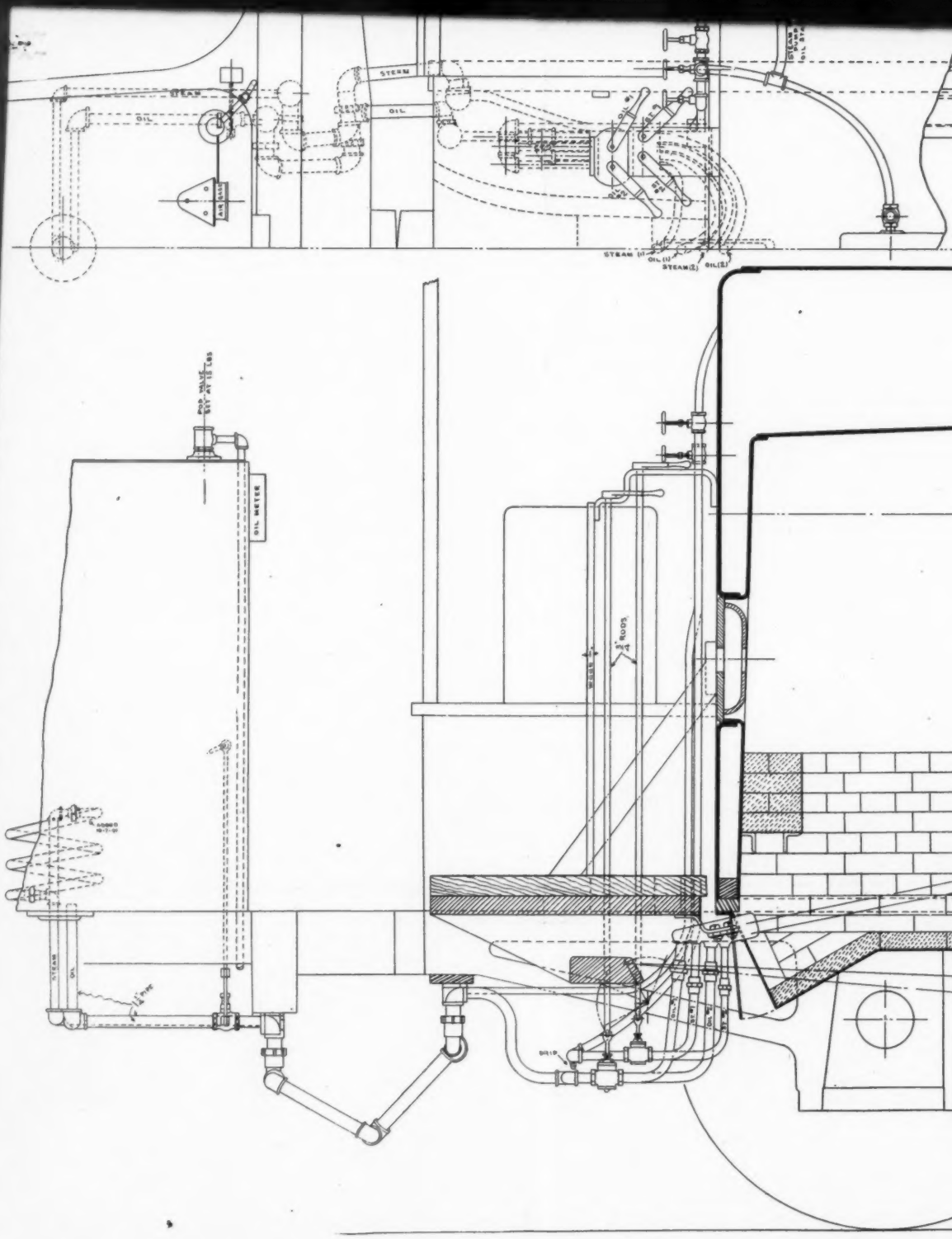


OIL FUEL ARRANGEMENT FOR



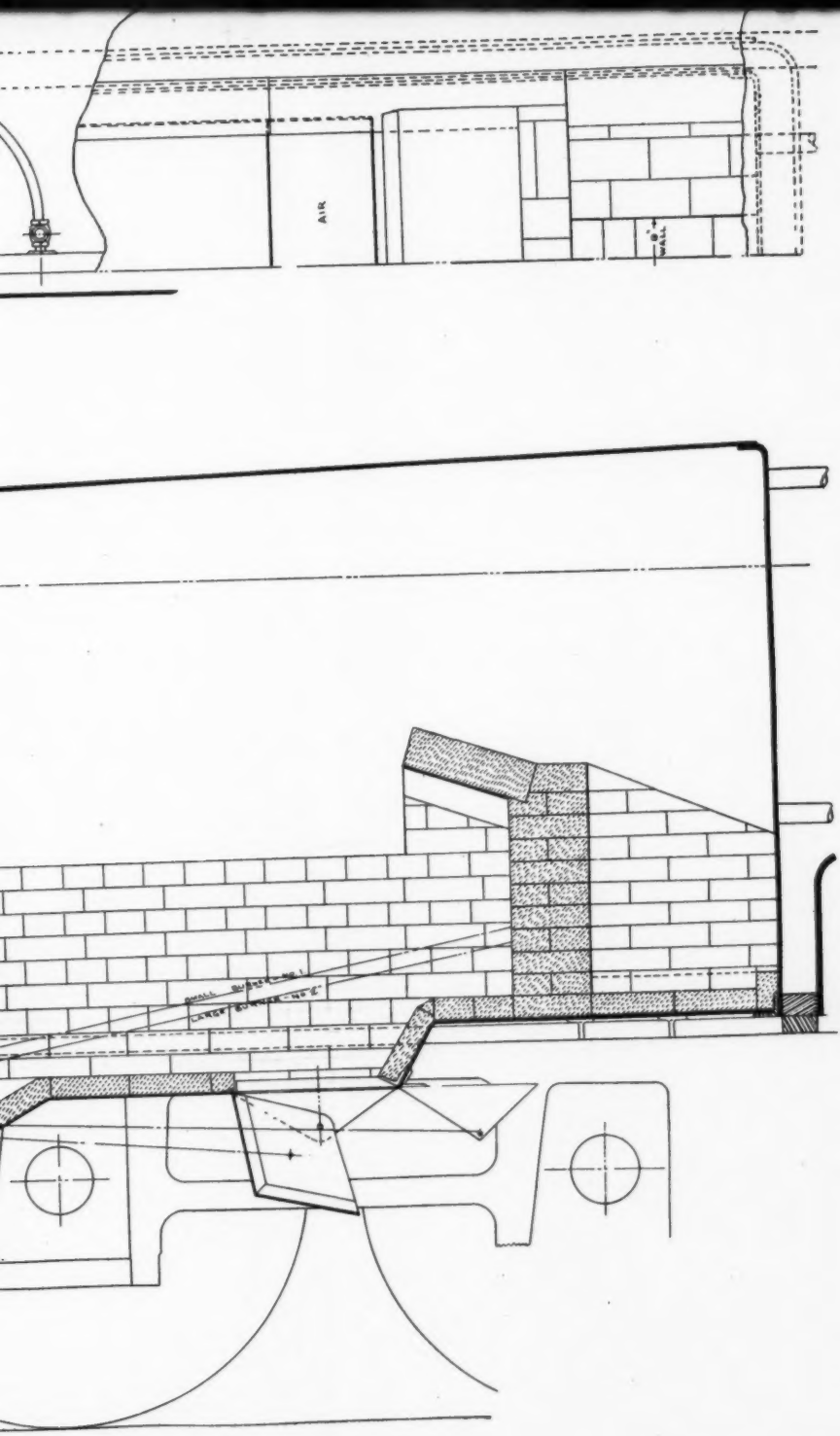
GEMENT FOR LOCOMOTIVE WITH ORDINARY TYPE, LONG FIRE BOX.

PLATE No. 1.

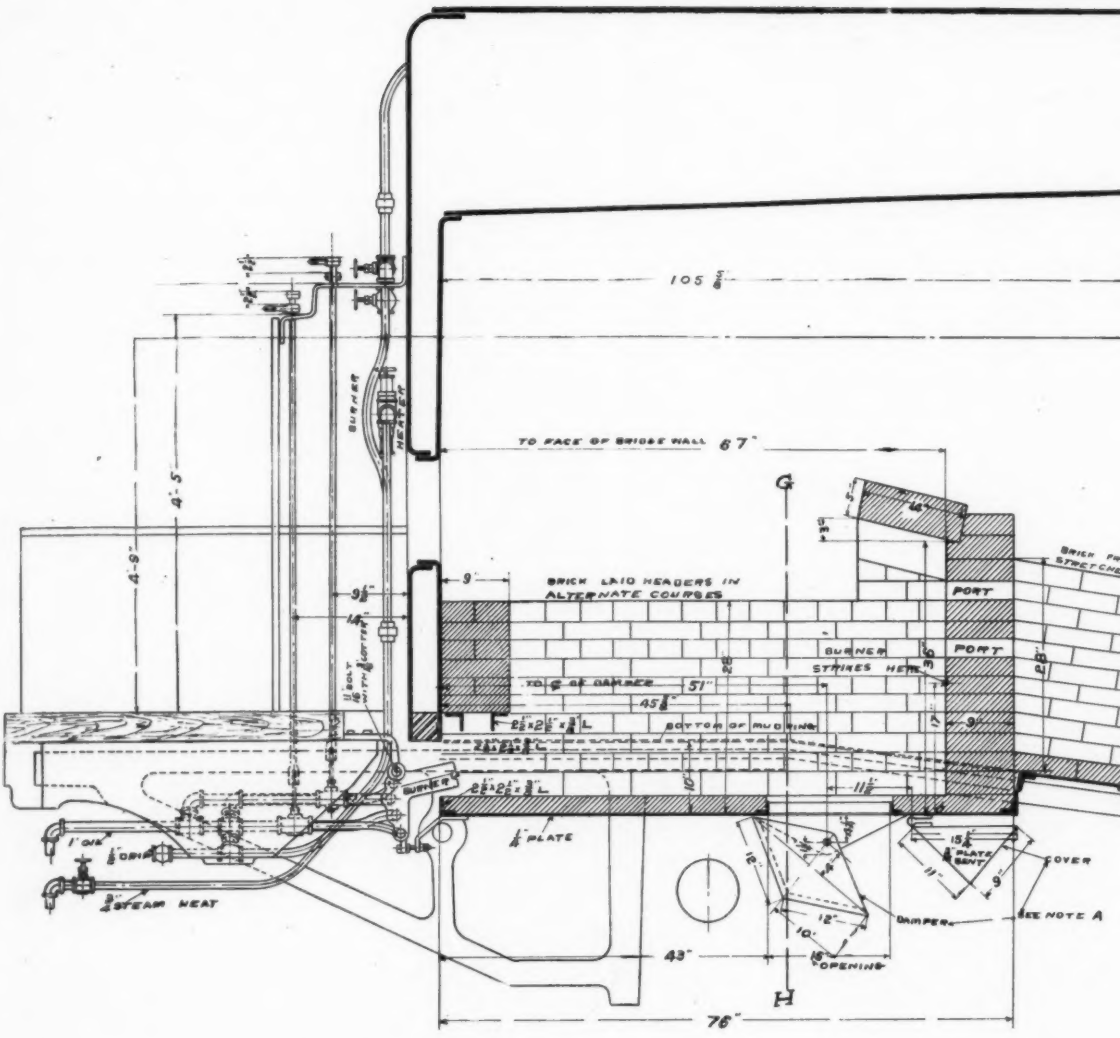


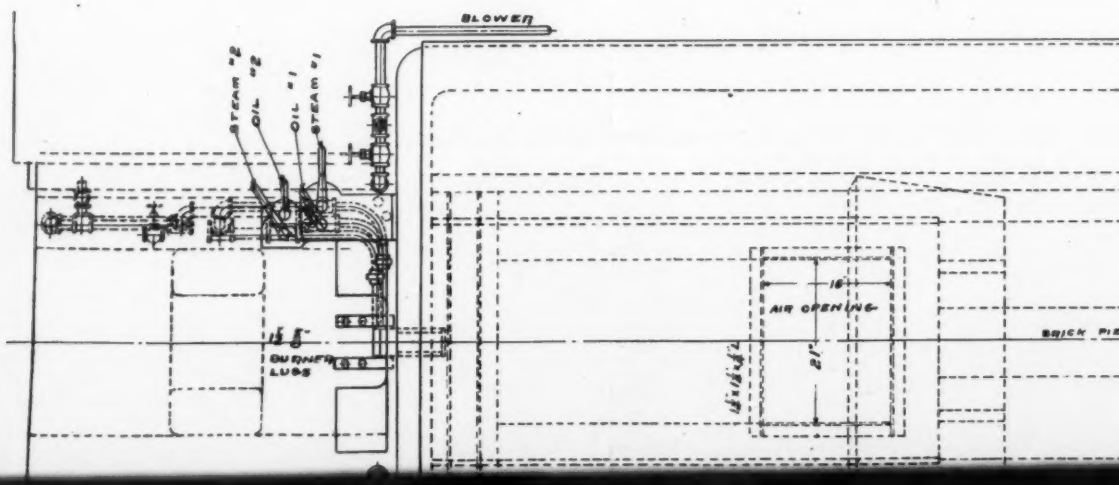
OIL FUEL ARRANGEMENT FOR LOCOMOTIVE WITH ORDINARY TYPE, LONG FIRE BOX.

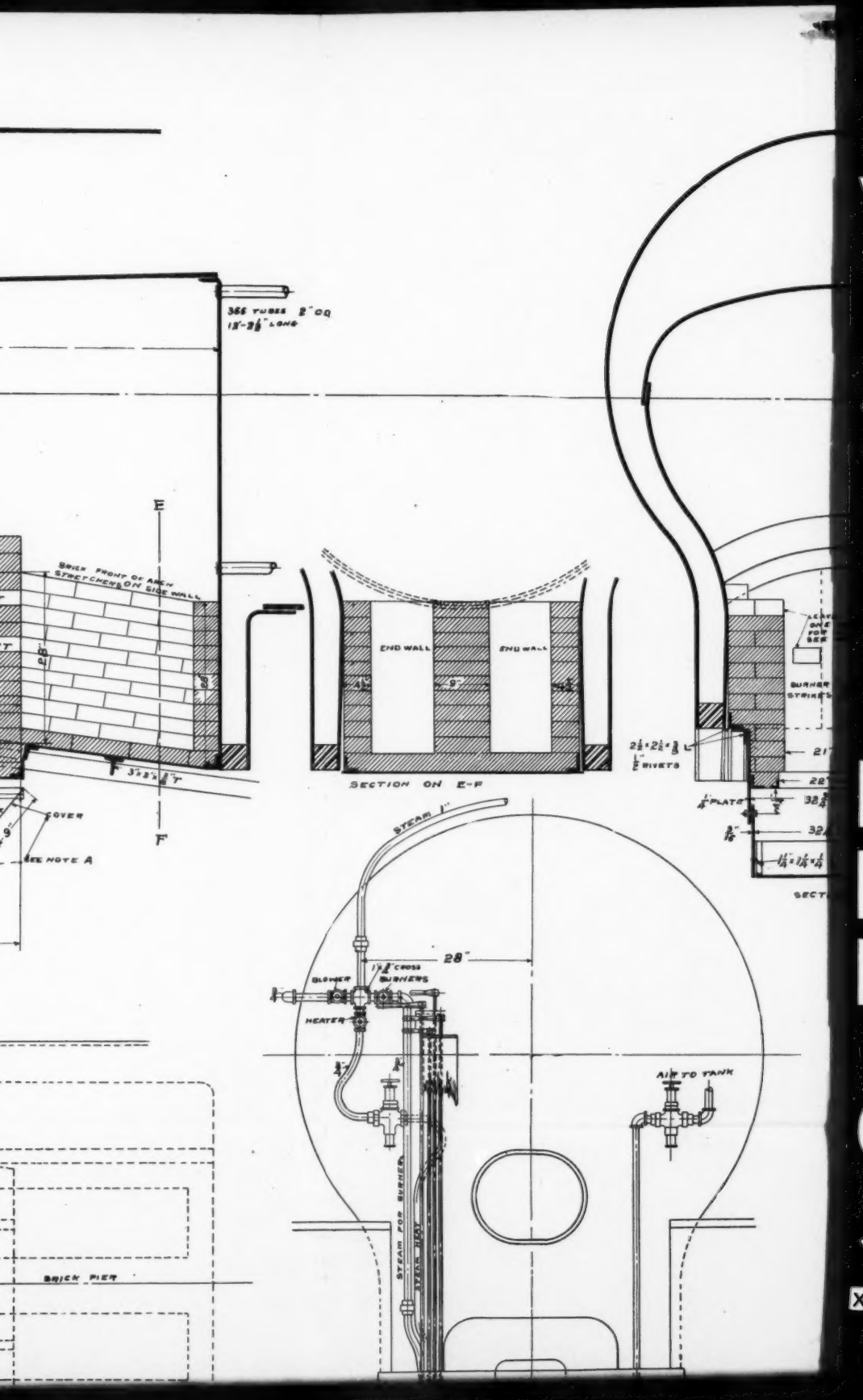
PLATE No. 1.

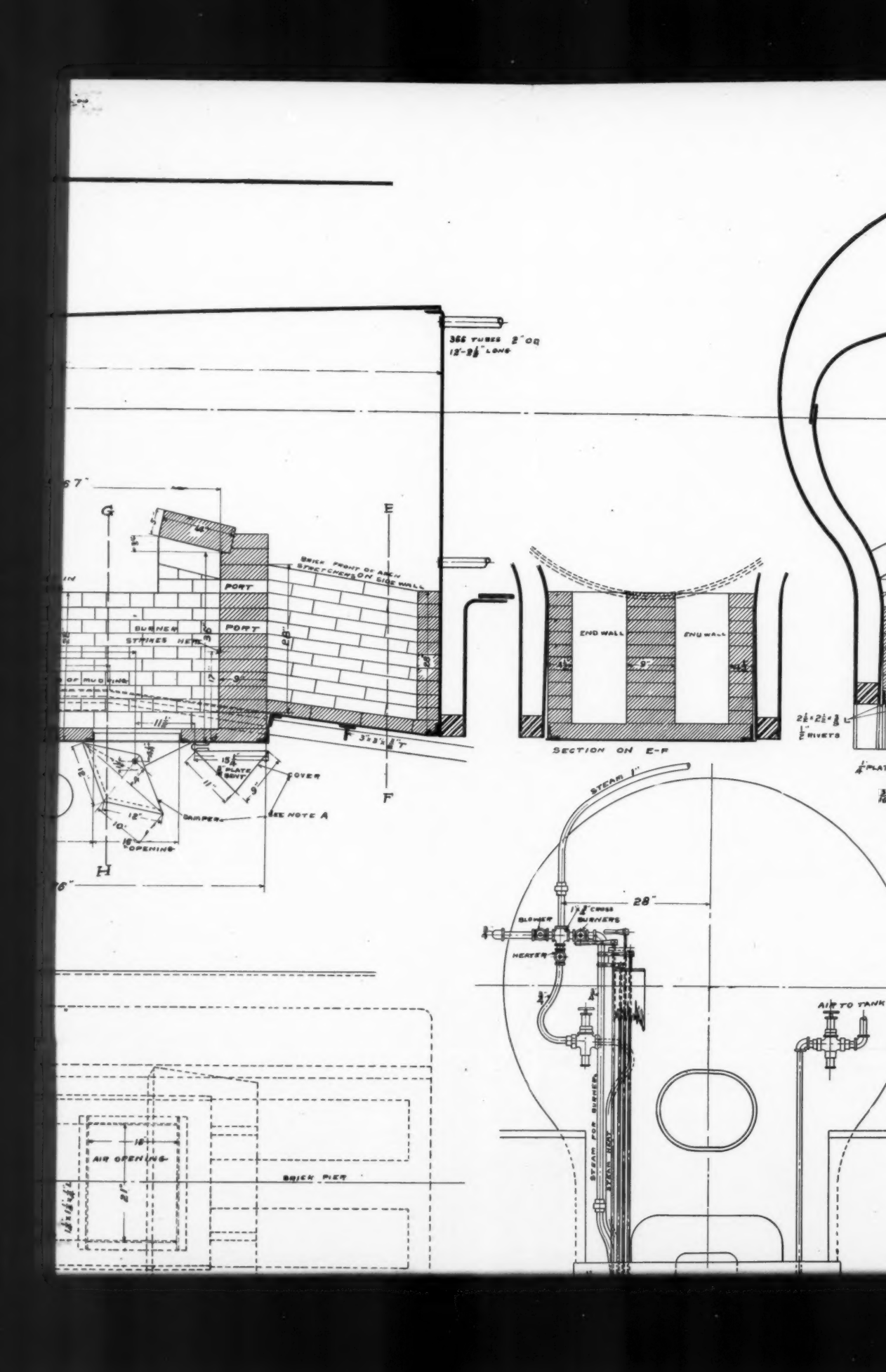


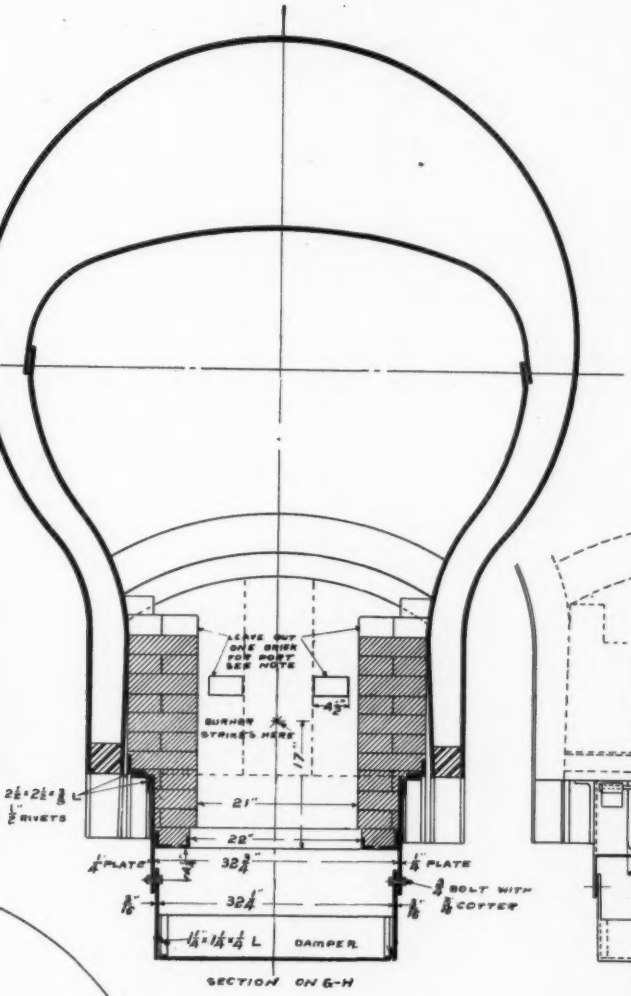
e Box.

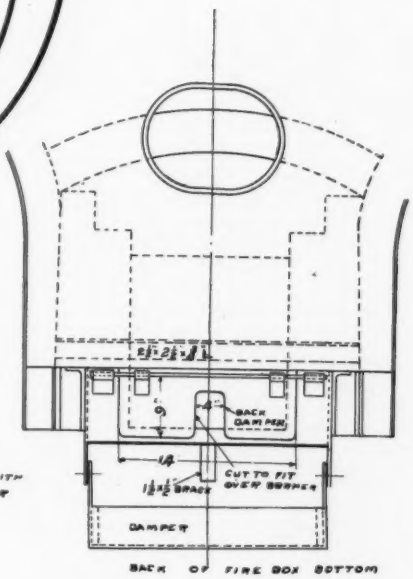

105 5/8"
TO FACE OF BRIDGE WALL 67"
4'-9"
4'-5"
BURNER
9"
9 1/2"
14"
BRICK LAID HEADERS IN ALTERNATE COURSES
PORT
BURNER STRIKES HERE
TO ℄ OF DAMPER 51"
45 5/8"
BOTTOM OF MUD RING
2 1/2" x 2 1/2" x 3/8" L
2 1/2" x 2 1/2" x 3/8" L
BURNER
1" OIL
1/8" DRIP
3/4" STEAM HEAT
1/4" PLATE
12"
10"
11 1/2"
15 1/8" PLATE BENT
COVER
DAMPER
SEE NOTE A
43"
15" OPENING
76"


BLOWER
STEAM #2
OIL #2
OIL #1
STEAM #1
15 5/8"
BURNER LUGS
16"
AIR OPENING
21"


366 TUBES 2" OD
15'-2⅝" LONG
E
F
BRICK FRONT OF ARCH STRETCHERS ON SIDE WALL
END WALL
END WALL
SECTION ON E-F
COVER
SEE NOTE A
STEAM 1"
28"
BLOWER
1½" CROSS BURNERS
HEATER
AIR TO TANK
STEAM FOR BURNER
BRICK PIER


366 TUBES 2" OD
12'-2½" LONG
BRICK FRONT OF ARCH STRETCHERS ON SIDE WALL
PORT
BURNER STRIKES HERE
PORT
END WALL
END WALL
SECTION ON E-F
15" PLATE DEFLECTOR
COVER
DAMPER
SEE NOTE A
16" OPENING
STEAM 1"
28"
1½" CROSS BURNERS
BLOWER
HEATER
AIR TO TANK
STEAM FOR BURNER
STEAM BODY
AIR OPENING
BRICK PIER

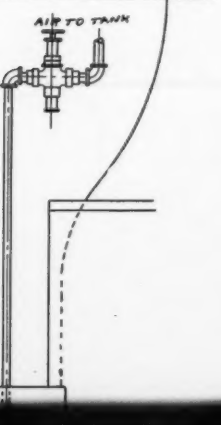




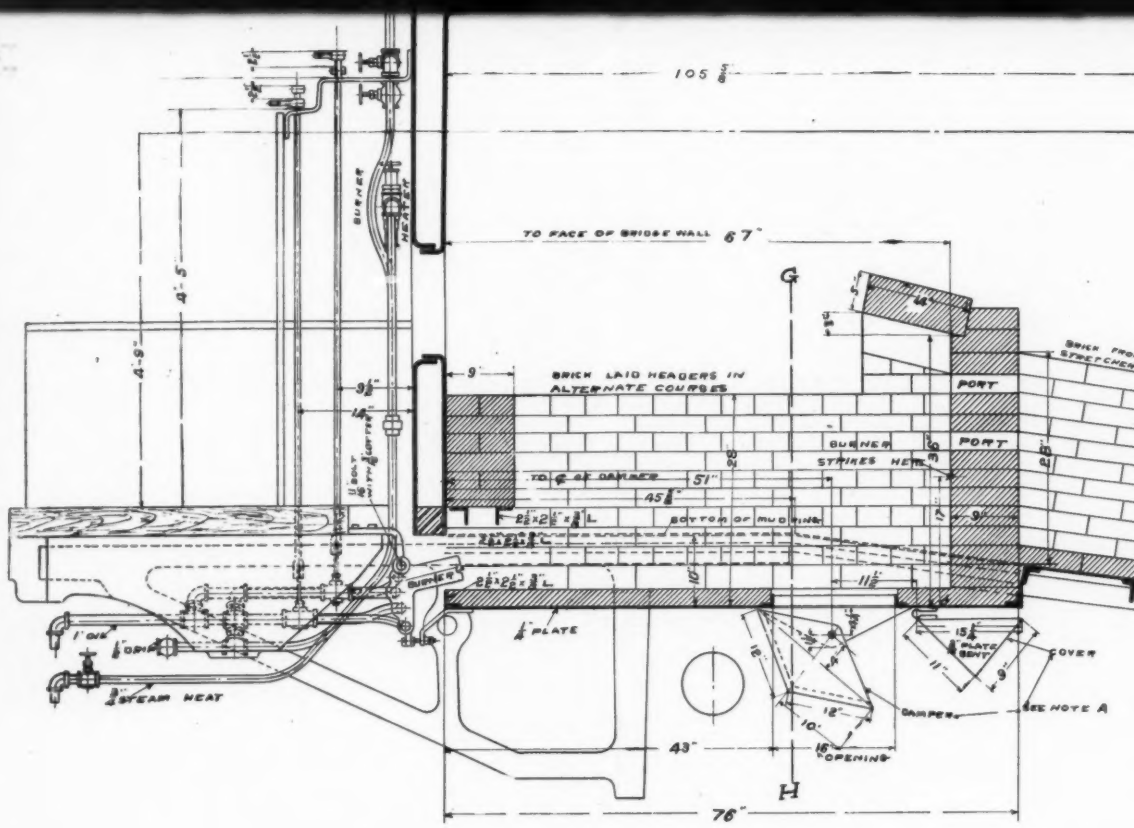
NOTE-A- DAMPER TO HAVE ROD TO CAB AND TO SWING OPEN FRONT AND BACK OPEN SIDE ALWAYS OPPOSITE TO DIRECTION ENGINE IS RUNNING COVER DROPS OVER DAMPER WHEN OPEN TOWARDS FRONT. BACK DAMPER AND COVER TO HAVE RODS TO CAB

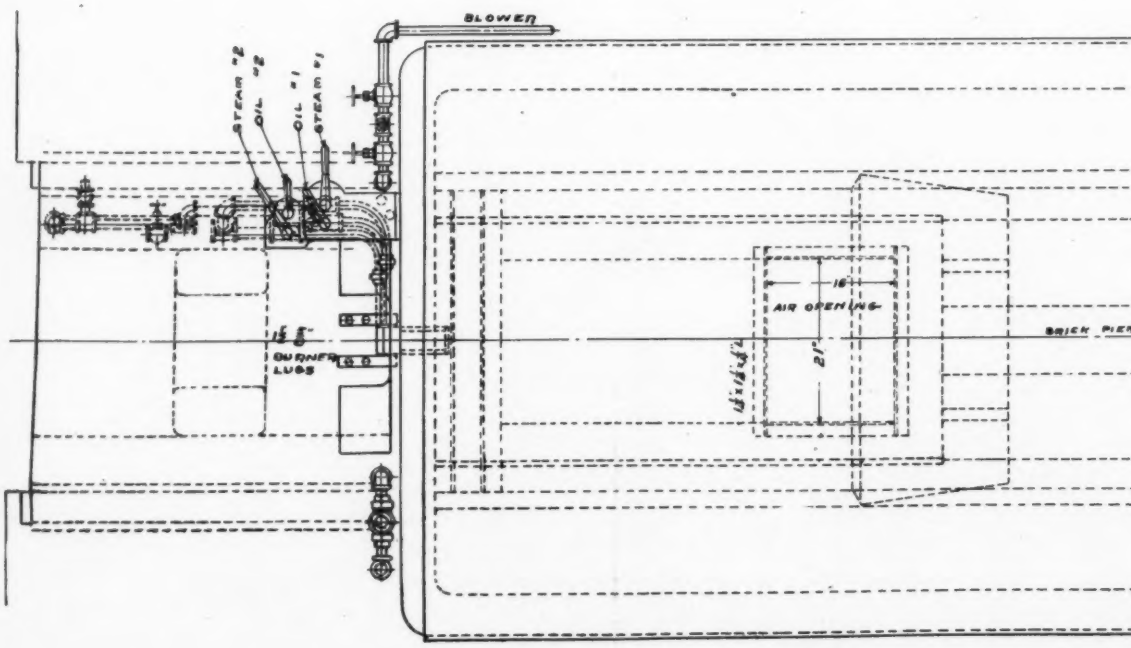
NOTE-B- LEAVE OUT ONE BRICK HEADER IN EACH SIDE 9TH COURSE FROM BOTTOM NEXT TO CENTRE WALL
LEAVE OUT ONE BRICK HEADER IN EACH SIDE 12TH COURSE FROM BOTTOM NEXT TO SIDE WALLS

NOTE-C BURNER #1 = SMALL OR UPPER BURNER
" 2 = LARGE " LOWER "



OIL FUEL ARRANGEMENT


105 5/8
TO FACE OF BRIDGE WALL 67"
BRICK LAID HEADERS IN ALTERNATE COURSES
PORT
PORT
BURNER STRIKES HERE
TO ℄ OF DAMPER
51"
45"
BOTTOM OF MUD RING
BURNER
BURNER
4'-5"
4'-5"
9 1/2"
9"
1" OIL
1" DRIP
3/4" STEAM HEAT
1/4" PLATE
15 1/4"
PLATE BENT
COVER
DAMPER
SEE NOTE A
43"
16" OPENING
76"
G
H


BLOWER
STEAM "2
OIL "2
OIL "1
STEAM "1
1 5/8"
BURNER LUGS
16"
AIR OPENING
21"
BRICK PIER

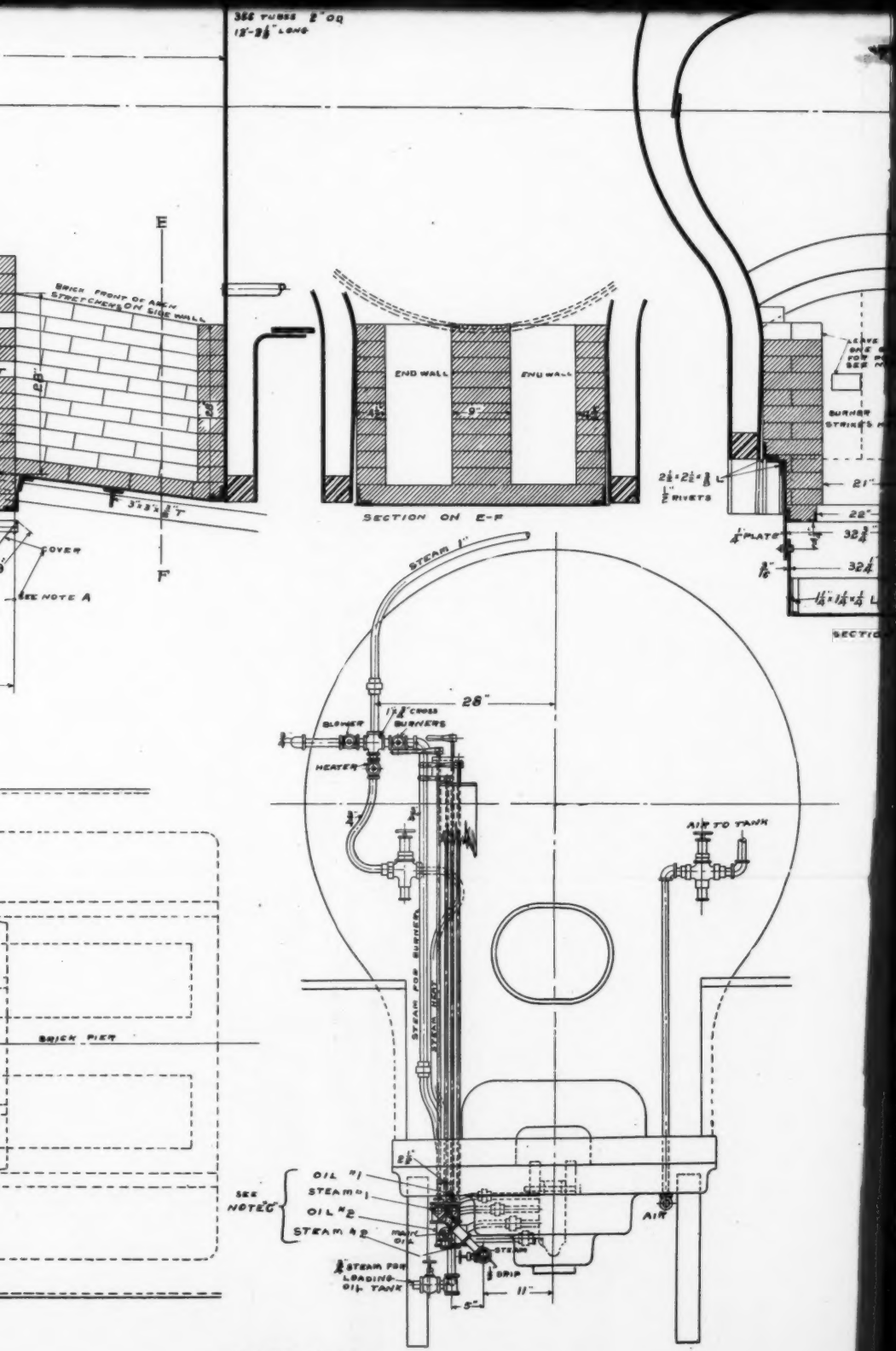

SEE TUBES 2" OD
13'-2½" LONG
E
F
BRICK FRONT OF ARCH
STRETCHERS ON SIDE WALL
END WALL
END WALL
SECTION ON E-F
COVER
SEE NOTE A
STEAM 1"
28"
1¼" CROSS
BURNERS
BLOWER
HEATER
AIR TO TANK
STEAM FOR BURNER
BRICK PIER
OIL #1
STEAM #1
OIL #2
STEAM #2
SEE NOTE C
MAIN OIL
STEAM
AIR
STEAM FOR LOADING OIL TANK
DRIP
11"
5"
2½"
21"
22"
32¾"
32¼"
1" RIVETS

PLATE No. 1a.

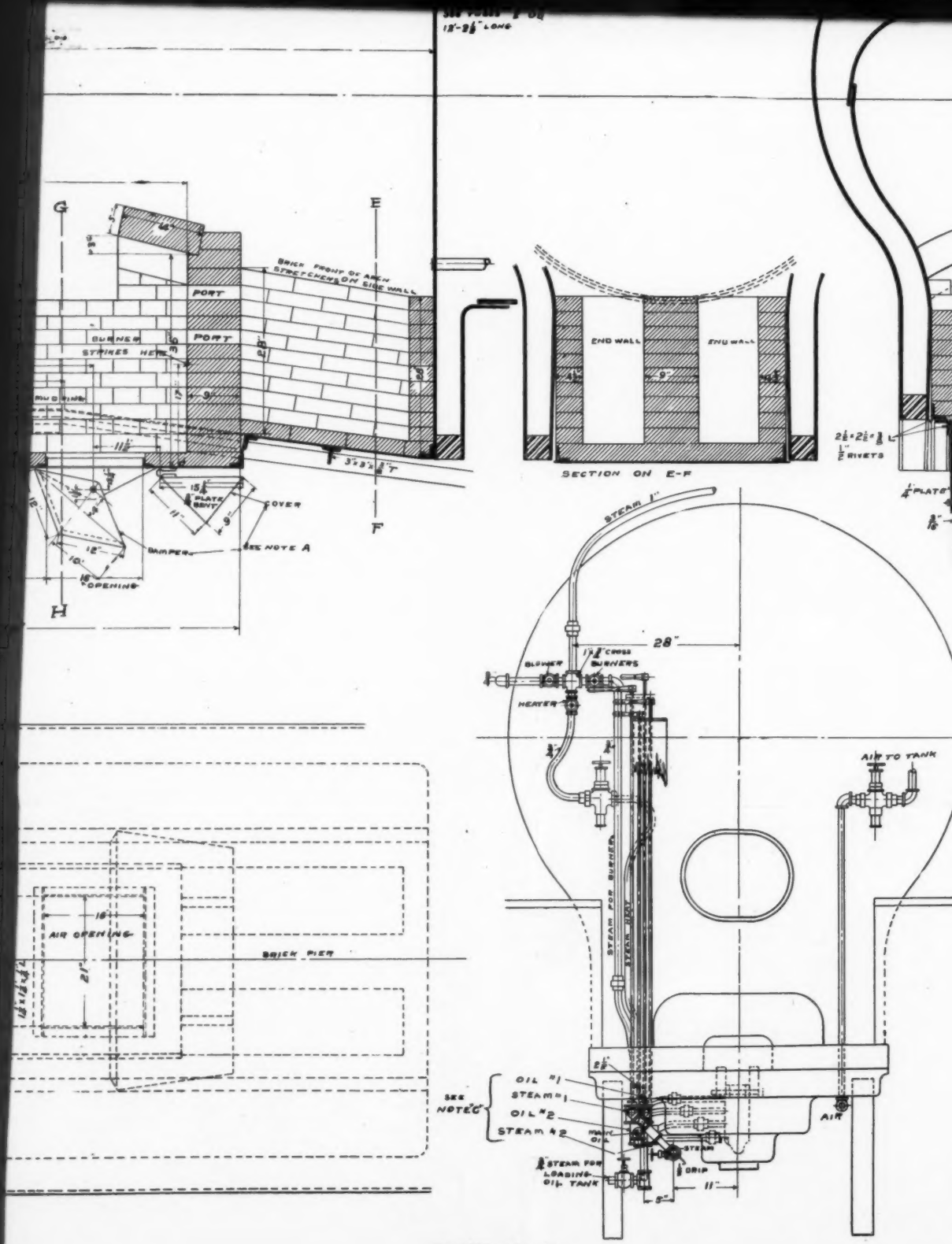
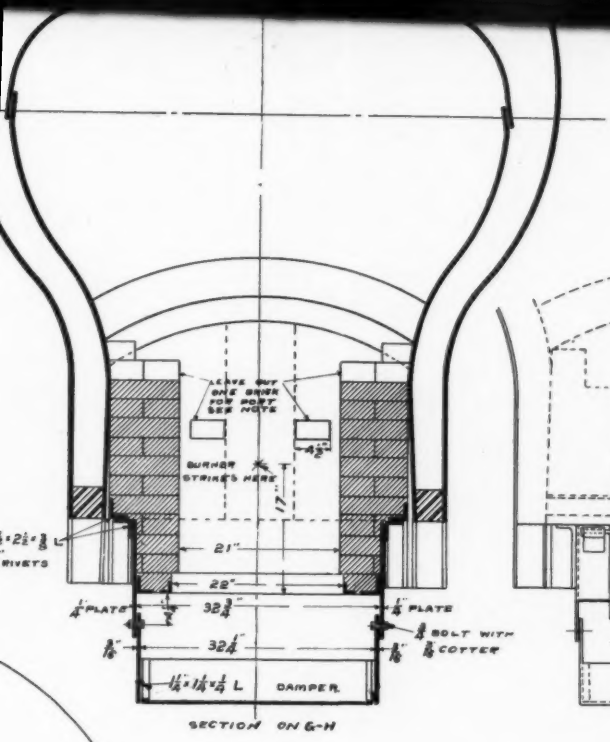
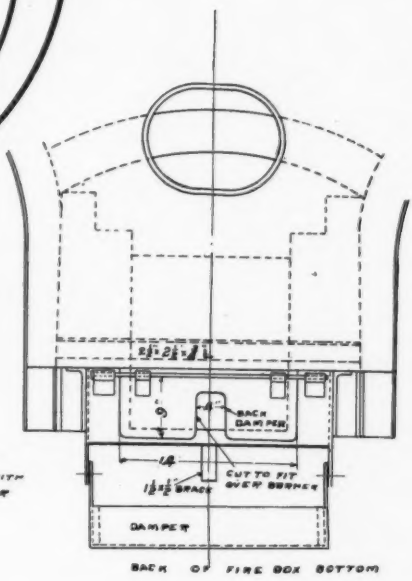
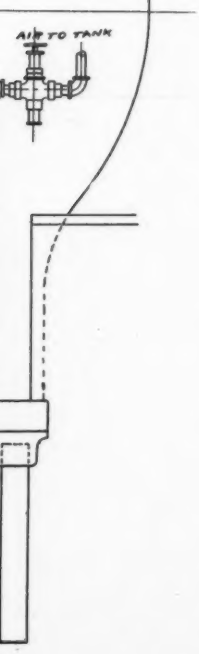

G
E
F
H
PORT
PORT
BURNER STRIKES HERE
BRICK FRONT OF ARCH STRETCHERS ON SIDE WALL
END WALL
END WALL
SECTION ON E-F
COVER
BUMPER
SEE NOTE A
OPENING
AIR OPENING
BRICK PIER
STEAM 1"
BLOWER
HEATER
28"
AIR TO TANK
STEAM FOR BURNER
STEAM JET
OIL #1
STEAM #1
OIL #2
STEAM #2
SEE NOTE C
AIR
STEAM
GRIP
STEAM FOR LOADING OIL TANK
11"

PLATE No. 1a.







NOTE-A- DAMPER TO HAVE ROD TO CAB AND TO SWING OPEN FRONT AND BACK OPEN SIDE ALWAYS OPPOSITE TO DIRECTION ENGINE IS RUNNING COVER DROPS OVER DAMPER WHEN OPEN TOWARDS FRONT. BACK DAMPER AND COVER TO HAVE RODS TO CAB

NOTE-B- LEAVE OUT ONE BRICK HEADER IN EACH SIDE 9TH COURSE FROM BOTTOM NEXT TO CENTRE WALL
LEAVE OUT ONE BRICK HEADER IN EACH SIDE 12TH COURSE FROM BOTTOM NEXT TO SIDE WALLS

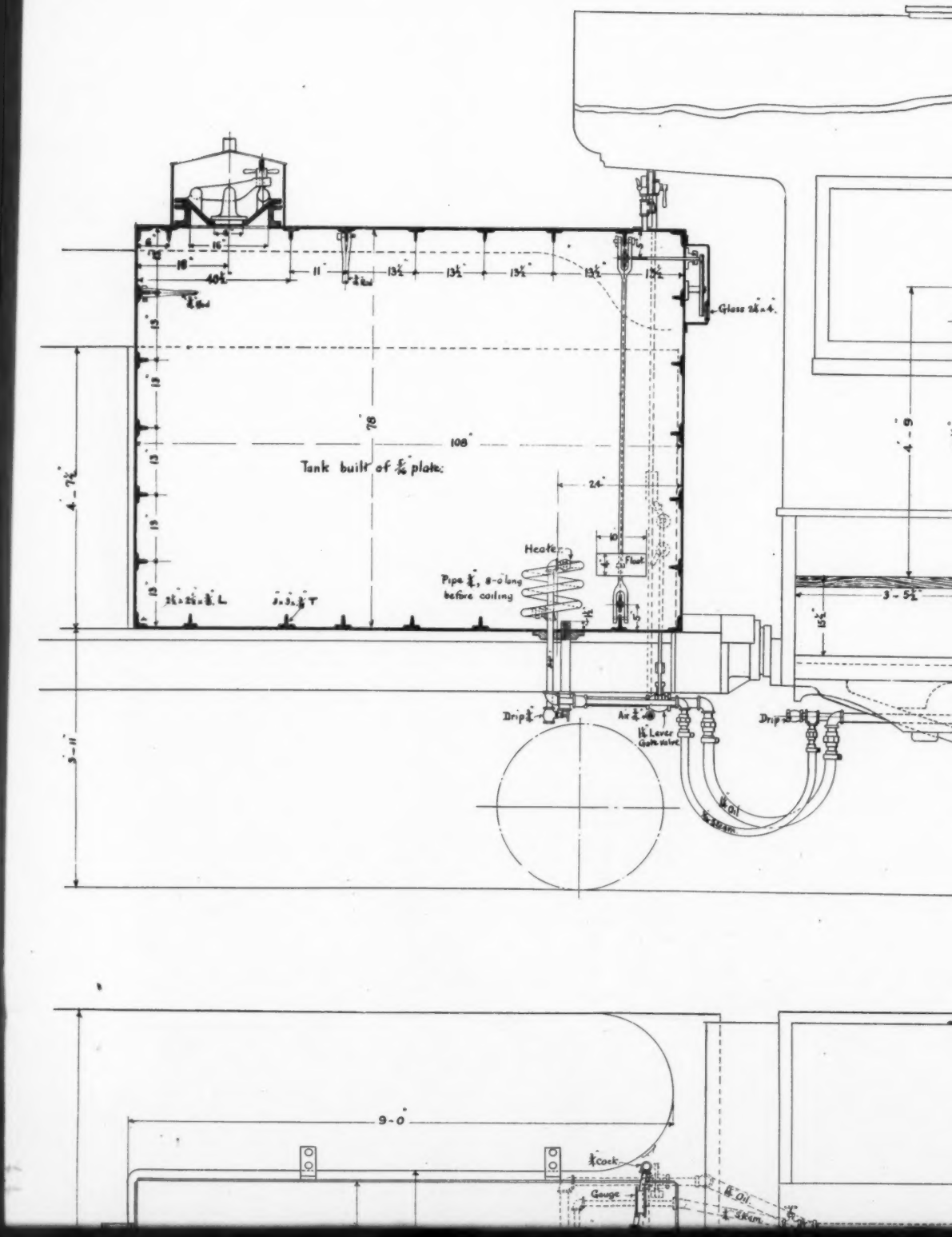
NOTE-C BURNER #1 = SMALL OR UPPER BURNER
" 2 = LARGE " LOWER "

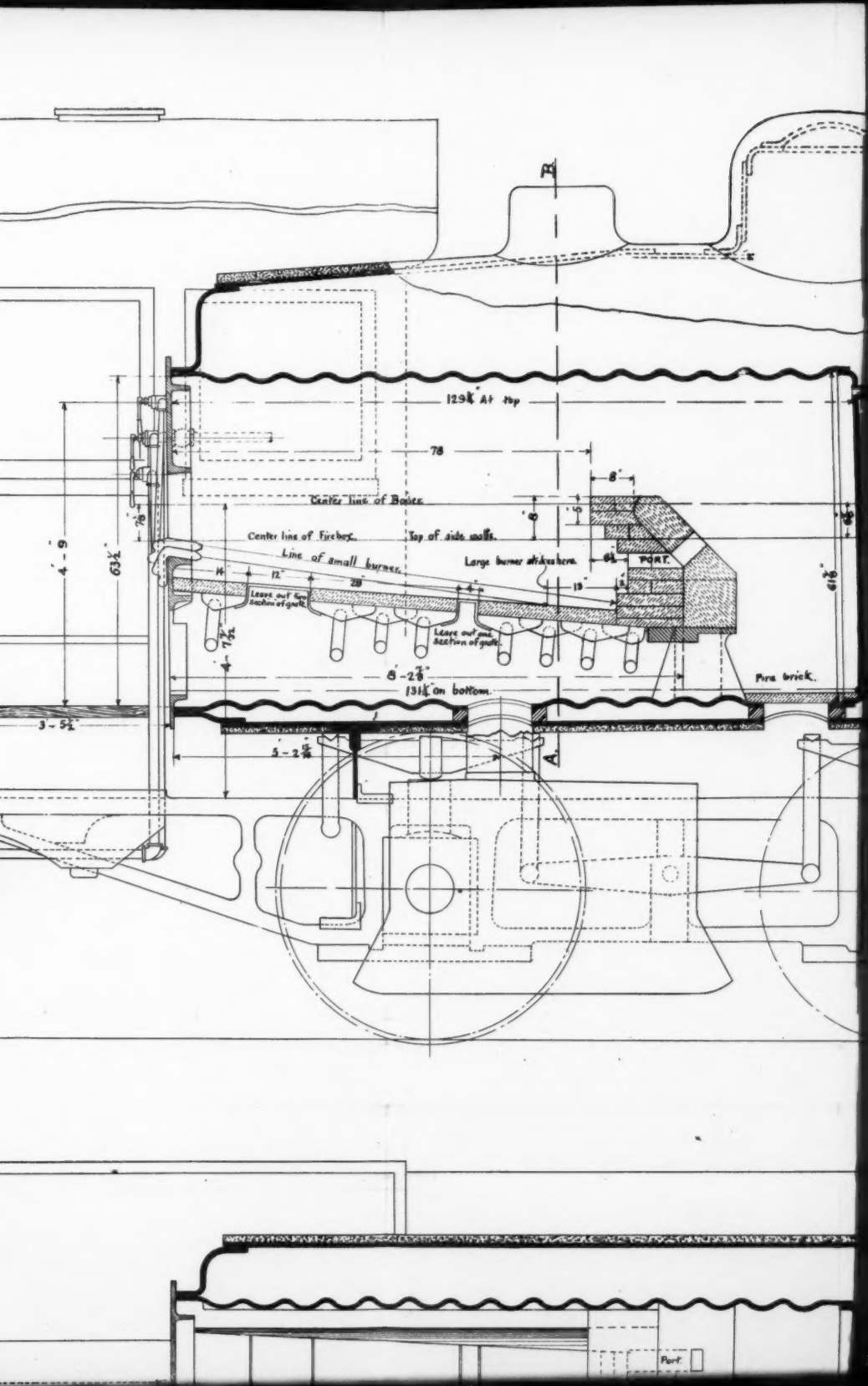
OIL FUEL ARRANGEMENT

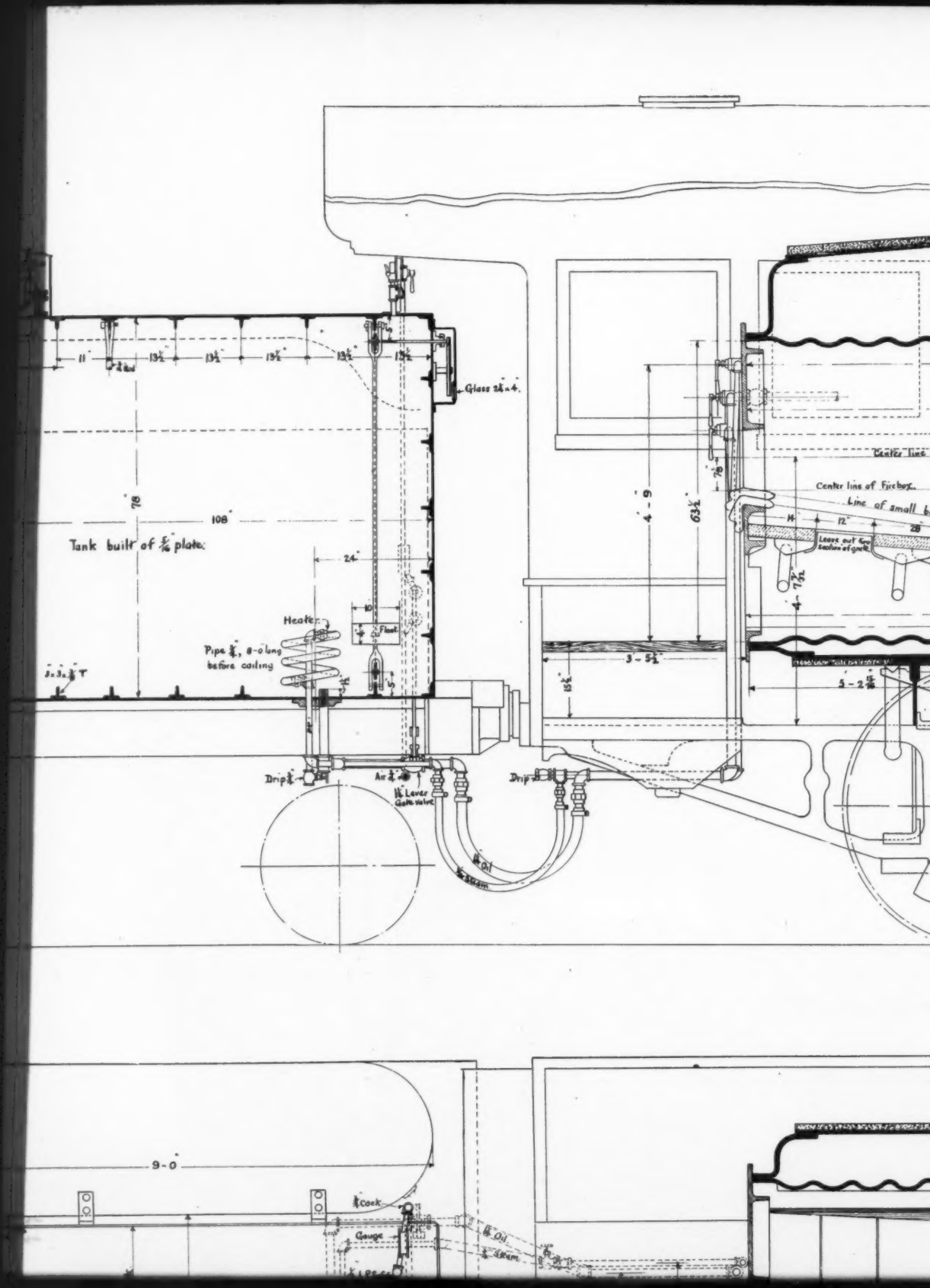
FOR LOCOMOTIVE N.Y.C & H.R.R.

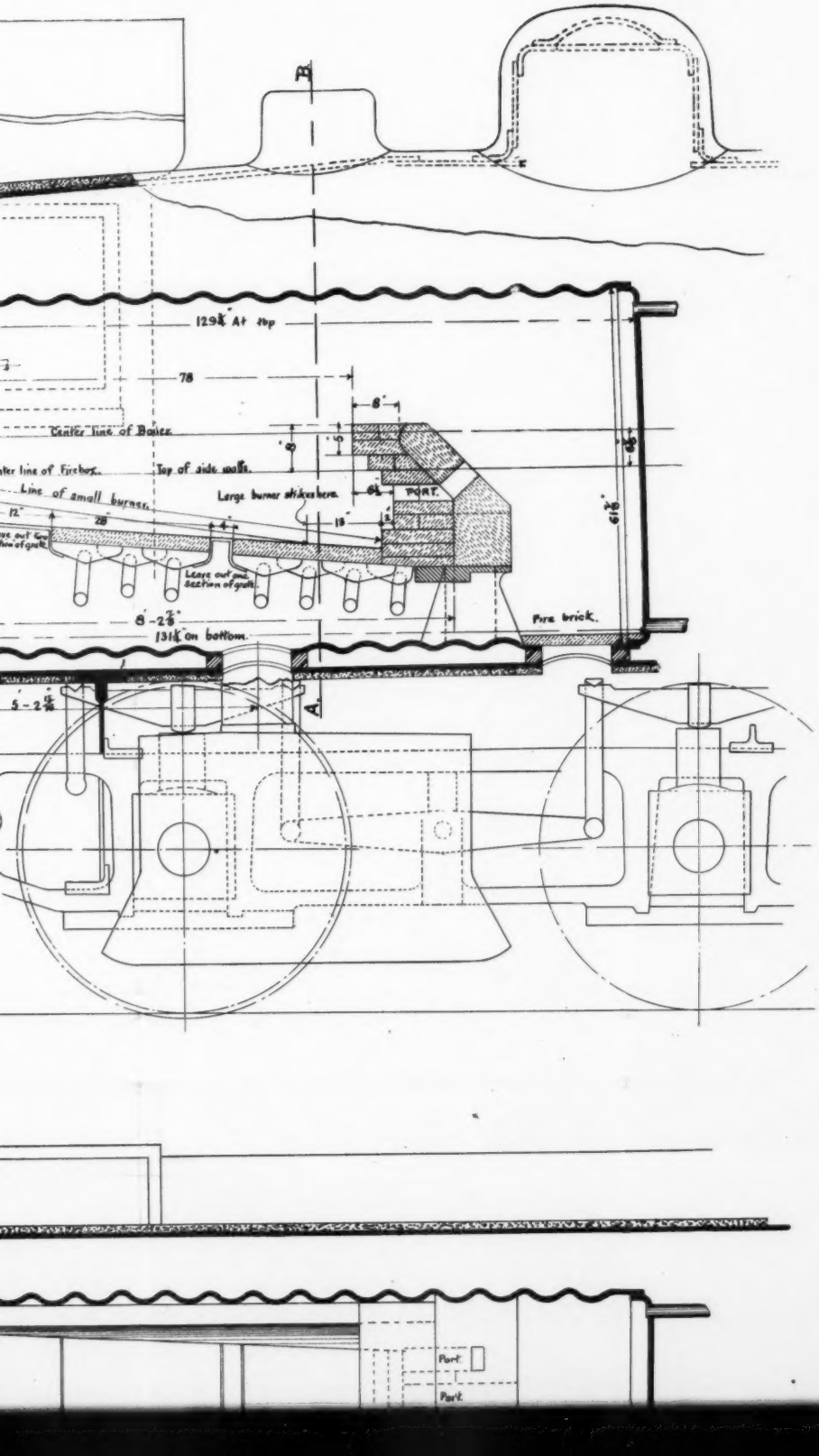
ENGINE DETAILS FROM "MOGUL ENGINE ERECTING CARD $\frac{X}{3782}$ A

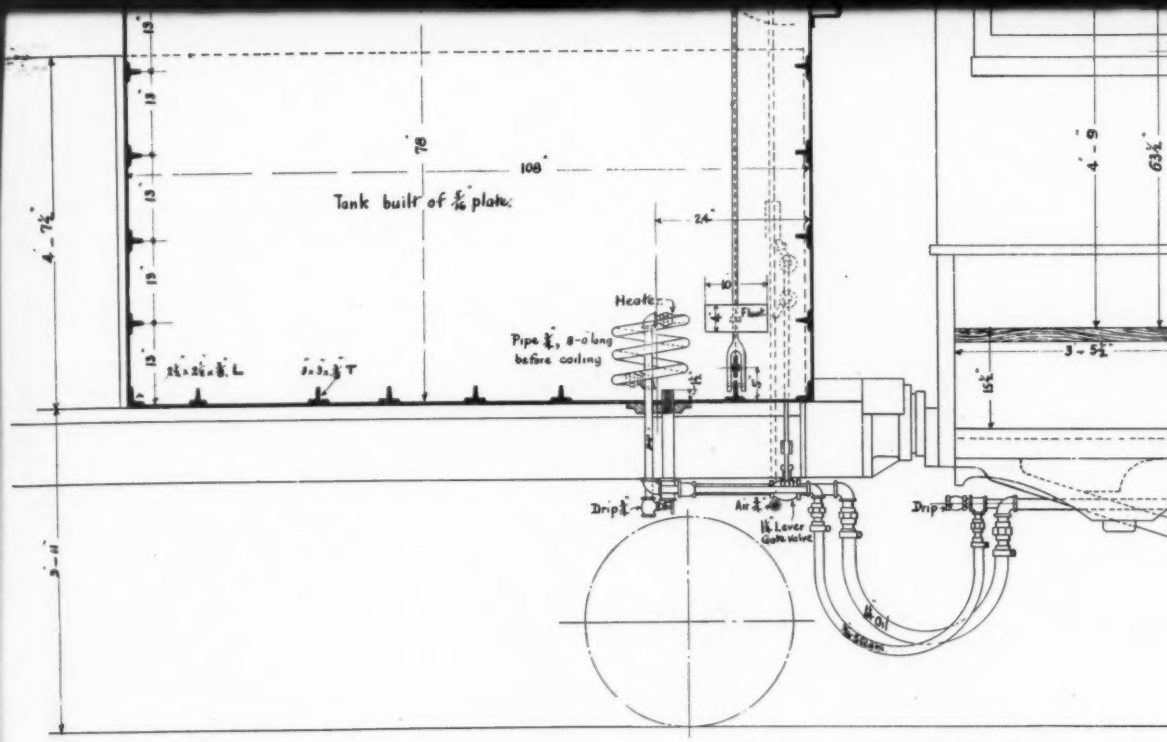
SCALE ½"=1'


Glass 24 x 4
78
108
Tank built of 5/16 plate
24
Heater
Float
Pipe 1/2, 8-0 long before coiling
Drip 1/2
Air 1/2
1 1/2 Lever Gate Valve
Drip 1/2
4 - 7 1/2
3 - 11
4 - 9
3 - 5 1/2
9 - 0
1/2 Cock
Gauge
1/2 Oil


A
129¾" At top
78
8"
Center line of Boiler.
Center line of Firebox.
Top of side walls.
Line of small burner.
Large burner strikes here.
PORT.
Leave out 6" section of gate
Leave out 6" section of gate
8'-2⅞"
131¼" on bottom.
Fire brick.
4'-9"
63½"
3-5½"
5-2⅝"
A'
Port


Glass 2½ × 4
Tank built of ⅝ plate
Heater
Pipe ¾, 8-0 long before coiling
Float
Drip ¾
Air ¾
1½ Lever Gate valve
Drip ¾
¾ Oil
Center line
Center line of Fireboy
Line of small b
Leave out for bottom of gate
3 - 5½
5 - 2⅝
9-0
¾ Cock
Gauge
¾ Oil


B
129¾" At top
78
8"
Center line of Boiler.
Top of side walls.
Large burner strikes here.
PORT.
Line of small burner.
12"
28"
4"
19"
Leave out end section of grate.
Fire brick.
8'-2⅞"
131¼" on bottom.
A'
Port
Port


Tank built of ⅜" plate
108"
78"
24"
Heater
Pipe ¾", 8-0 long before coiling
Drip ¾"
Air ¾"
1½" Lever Gate Valve
Drip ¾"
1½" Oil
¾" Steam
4 - 7½"
3 - 11"
4 - 9"
63½"
3 - 5½"
15½"

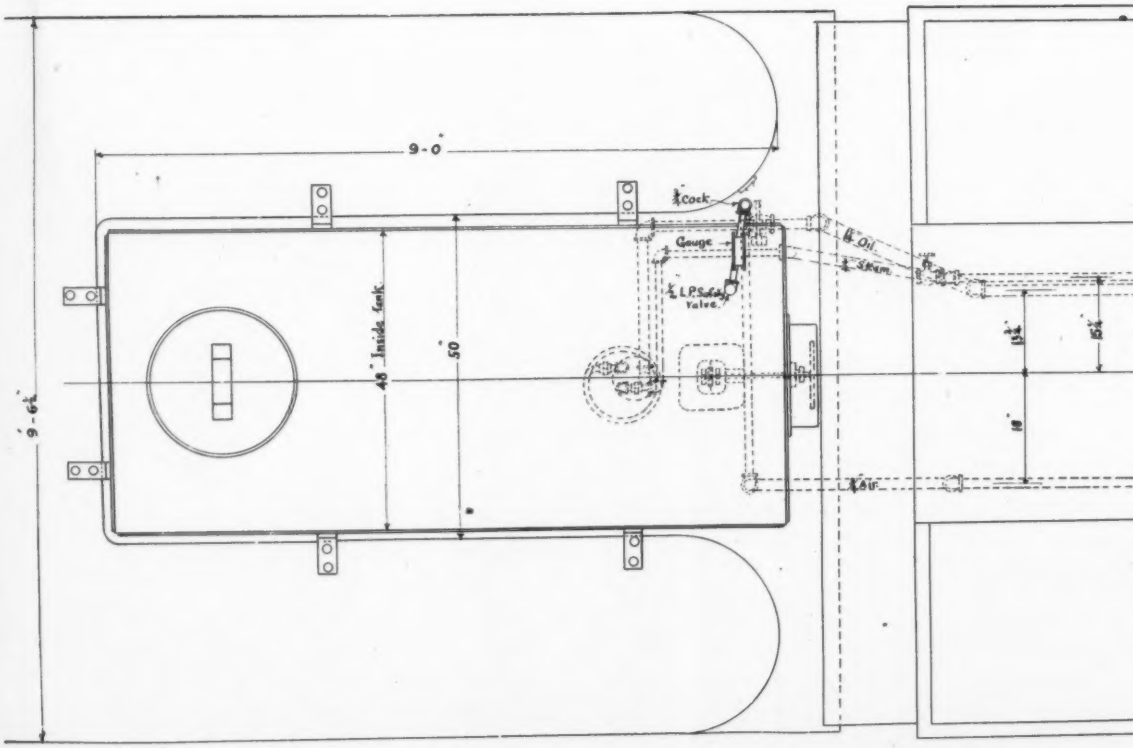

9 - 0"
¾" Cock
Gauge
¾" L.P.S. Valve
1½" Oil
¾" Steam
¾" Air
48" Inside tank
50"
9 - 6½"
13½"
15½"
18"

PLATE N

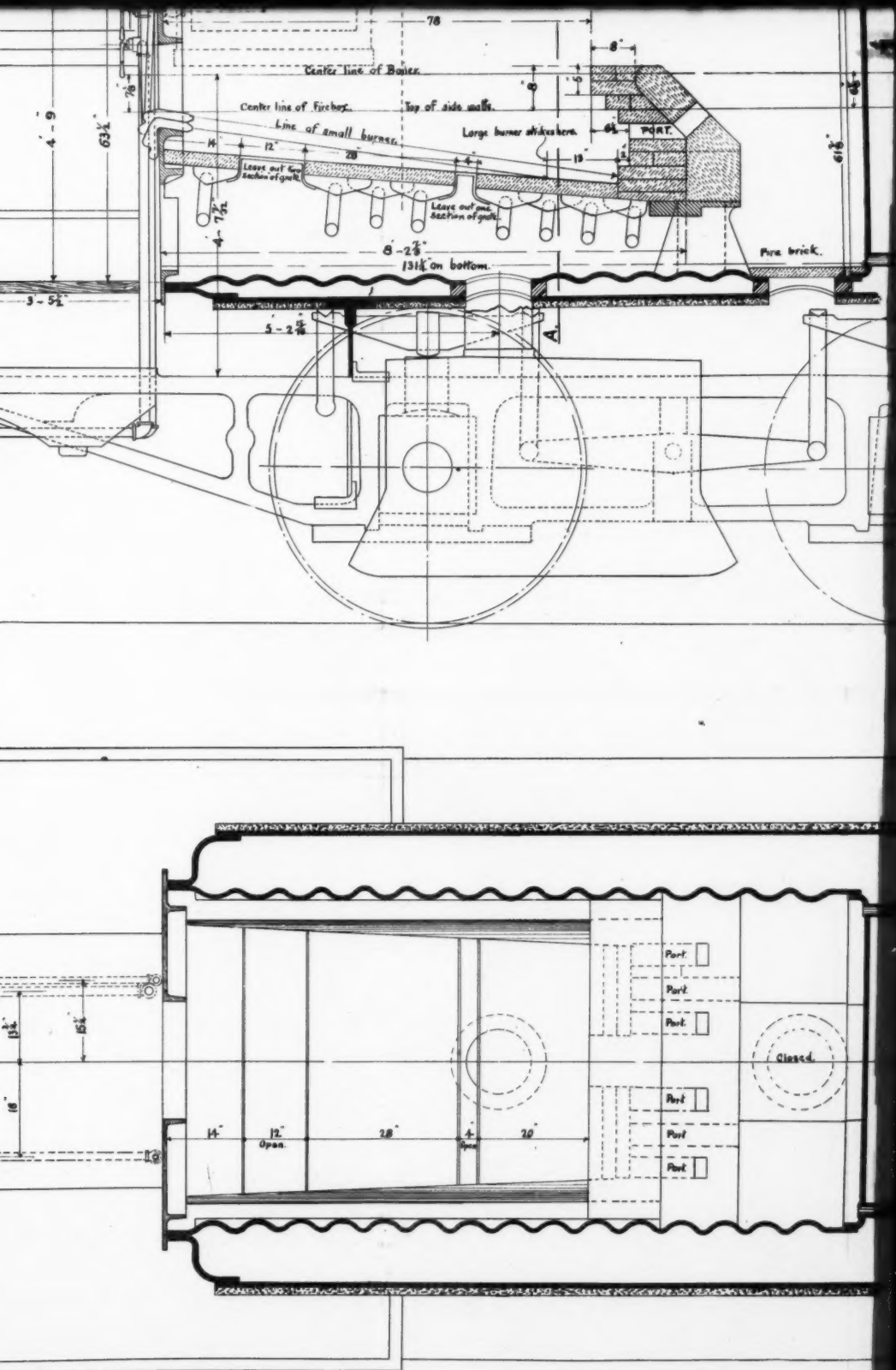

78
8"
Center line of Boiler.
Center line of Firebox.
Top of side walls.
Line of small burner.
Large burner strikes here.
PORT.
14"
12"
28"
19"
Leave out 6th section of grate
Leave out 3rd section of grate
7½"
8'-2½"
131¼" on bottom.
Fire brick.
4'-9"
63½"
3'-5½"
5'-2⅝"
A
A'
61⅝"
13½"
15½"
18"
12"
14"
12"
Open.
28"
4"
Open.
20"
Port.
Port.
Port.
Closed.
Port.
Port.
Port.

PLATE No. 2.

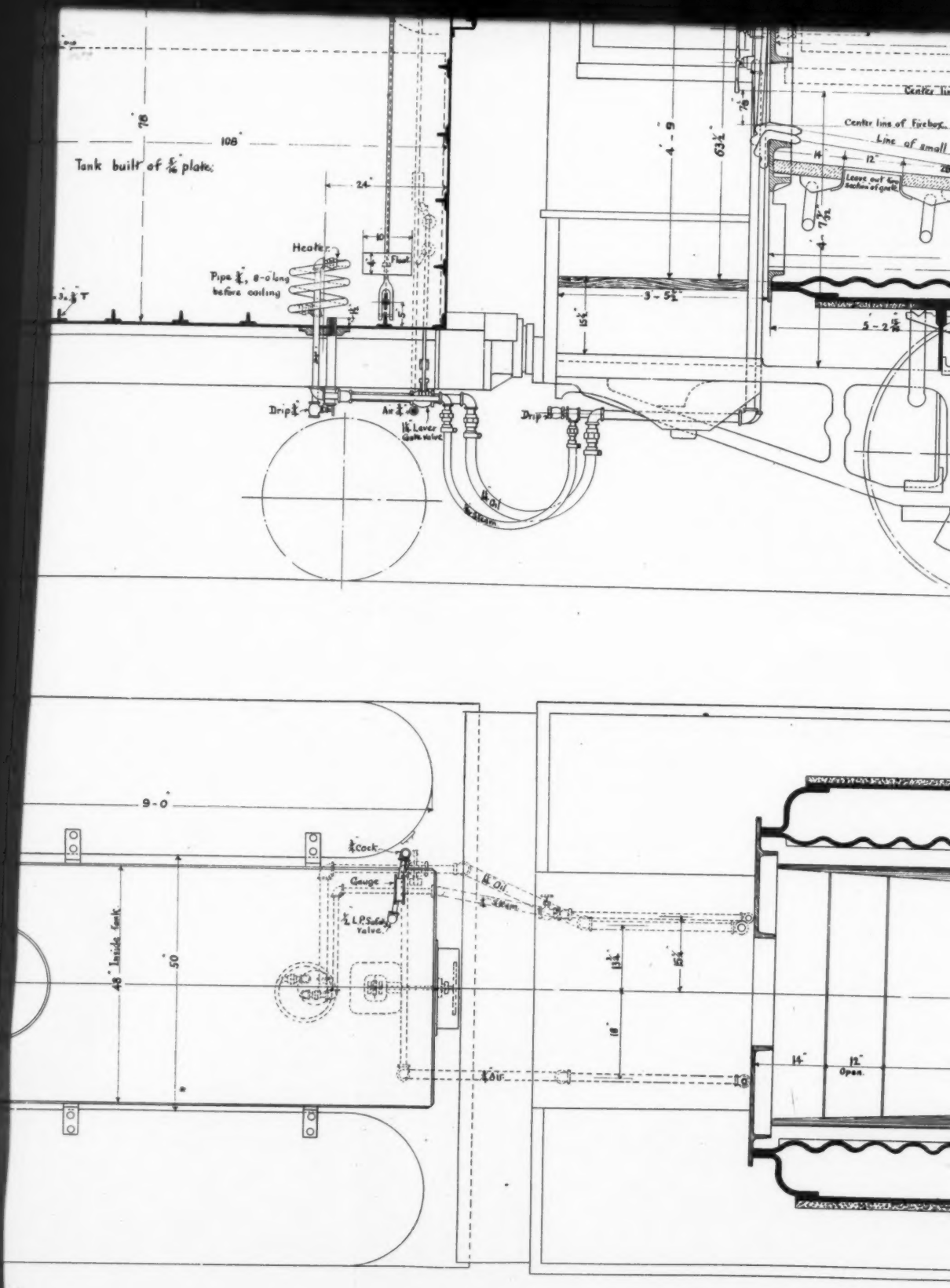
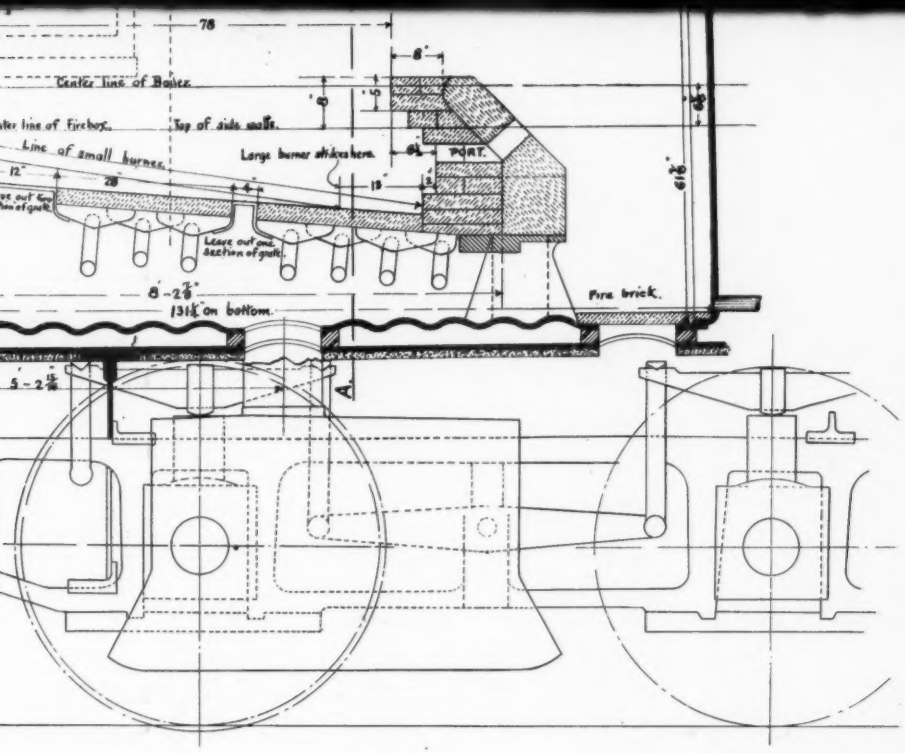
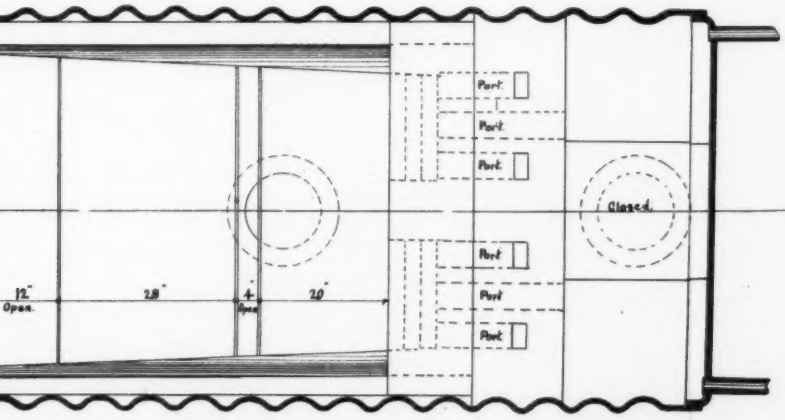
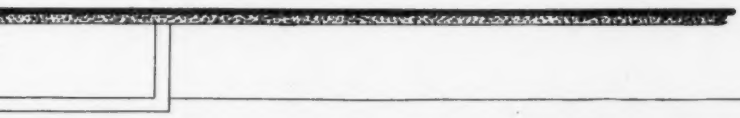

Tank built of 5/16" plate.
108"
78
24"
10"
Heater
Float
Pipe 1", 8'-0" long before coiling
3-3/8" T
Drip 1/2"
Air 1/2"
1/2" Lever Gate valve
Drip 1/2"
1/2" Oil
1/2" Steam
4'-9"
63 1/2"
Center line of Firebox
Line of small
14"
12"
Leave out two sections of grate
7 1/2"
3'-5 1/2"
15"
5'-2 3/16"
9'-0"
1/2" Cock
Gauge
1/2" L.P.S. Safety Valve
48" Inside tank
50"
1/2" Oil
1/2" Steam
13 1/2"
15 1/2"
18"
1/2" Oil
14"
12"
Open.

PLATE No. 2.


78
8"
Center line of Boiler.
Top of side walls.
Line of small burners.
Large burner strikes here.
PORT.
12"
28"
4"
15"
Leave out one section of grate.
8'-2⅞"
13½" on bottom.
Fire brick.
5'-2⅛"
A


Port
Port
Port
Closed.
Port
Port
Port
12"
Open.
28"
4"
Open
20"



TYPE OF FIRE BOX.

In comparing the locomotive fire box with the marine furnace, when using oil as fuel, the long, wide fire box closely approaches the cylindrical corrugated furnace of the marine type, and in late engines using the Vanderbilt type of fire box, the conditions are very similar.

Plates No. 1 and 1*a* show the setting of a locomotive fire box of the former type, while plates No. 2 and 2*a* show one of the Vanderbilt type.

In the latter the grate bars were left in place to support the paving of fire box, and therefore brings paving 10 inches to 12 inches higher than it would be if built for use of oil alone.

If we take the short, deep, locomotive box, say 60 inches length, 78 inches to 80 inches from bottom of fire-box ring to crown sheet, we shall have conditions which are present in the water-tube marine boilers. In the locomotive setting of the deep fire-box type, plate No. 1, the arch wall is placed against the forward sheet of the fire box, the arch projecting back one-third the length of the fire box, and allowing an area over the top of arch at least equal to the area between back end of arch and back fire-box sheet.

Now, turning for a moment to plate 7, figure 1, we find the ordinary setting of a tubular boiler; the grates paved over with fire brick laid, on brick stretchers so as to leave an air space above grate, and extending to within 10 inches of the dead plates of fire doors. This 10-inch space extends across fire box and admits sufficient air for combustion. The bridge wall is set with a row of fire brick on edge spaced about 2 inches apart, forming a checker which may be raised by adding one or two courses at the spaces on sides of furnace. At the back of the boiler is a wall supported on two arches. The central pier between the arches is built around blow-off pipe, and the crowns of arches are about on a level with brick paving of furnace. This setting presents about the best conditions for oil firing. The burner being pointed to strike paving slightly in front of bridge wall, the flame is broken so that it cannot injure the shell over bridge. At the same time the air is brought through the opening at front

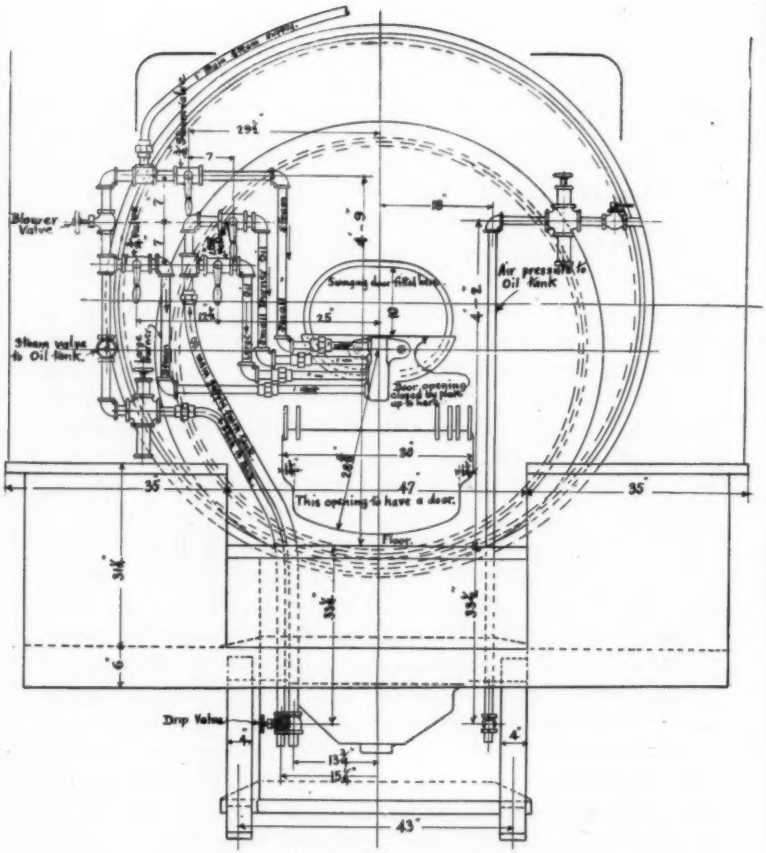
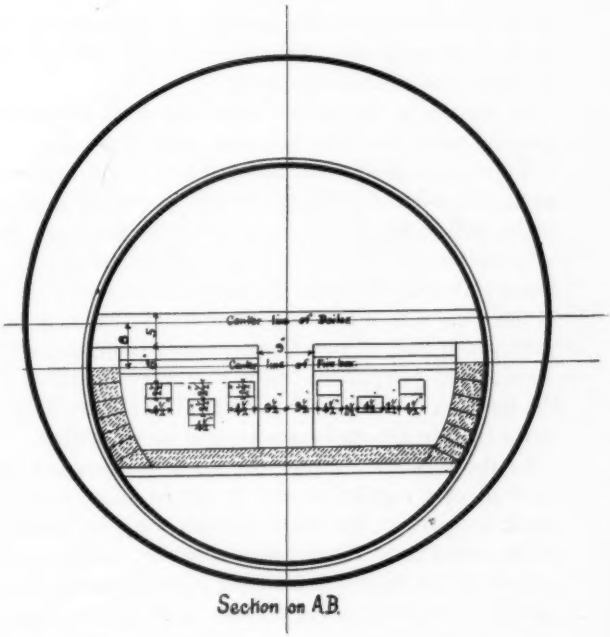


PLATE No. 2ª.——Fig. 1.



Scale 1- 1 ft.

Section on A.B.

Oil Fuel Arrangement
for
Locomotive
with Vanderbilt Fire box.
April 1902

PLATE No. 2a.——Fig. 2.

and thoroughly mixed before passing bridge wall. Back of the bridge is an ample combustion chamber, three sides of which are hot brick, and the arch wall holding the lighter gases in check until they pass into back connection through arches. It might be compared to a boiler set over a reverberatory furnace, and when running at rated capacity of boiler, the arch wall will be a bright red, no flame showing.

In forcing a locomotive boiler, the limit of smokeless fire is reached when the flame begins to enter the tubes.

Turning to plates No. 1 and No. 2, it will be seen that, so far as the shape and size of fire box will permit, the stationary tubular boiler setting has been followed, and the gases are given as long as possible for thorough mixture before striking the tube sheet. Upon this point depends the fuel efficiency and the elimination of smoke. The action of locomotive exhaust in stack gives a very sharp and, at times, intermittent draft, and when burning from 250 to 300 gallons (2,000 to 2,300 pounds) of oil per hour, the mixture of air must be perfected in a shorter time and smaller space than in the stationary tubular boiler setting.

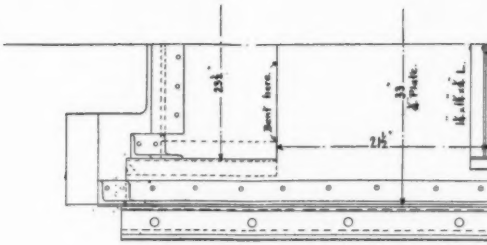
In the stationary setting the stack dampers and ash-pit doors give an easy regulation, and it will be found that with a proper stack proportion the stack damper may be closed two-thirds when running at rated boiler capacity. Here one of the difficulties of the locomotive setting is encountered, for the draft is entirely dependent on the capacity to which the engine is worked. This is always irregular, depending upon the train load and grades, and ceasing entirely when stops are made. To meet this the air is admitted to fire box through two openings, one at burner port when burner is set under fire-box ring, as in plate No. 1, and the other about under the back end of arch.

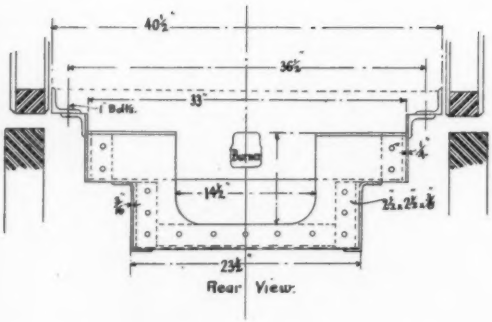
The admission of air at these points is regulated by dampers, the burner port being closed by a swinging door and the forward opening by a "scoop," arranged to be reversed when engine is backing or to be closed entirely when engine is stopped. A detail of this damper is shown in plate No. 3, and also an improved form in which two louvres swinging on trunnions are substituted for the "scoop."

BOSTON AND MAINE R.R.

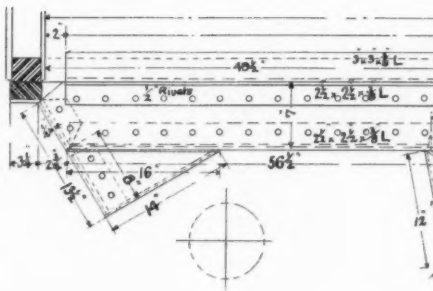
Motive Power Dep't.

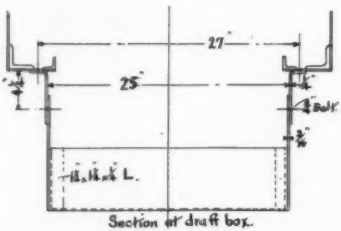
Ash Pan.



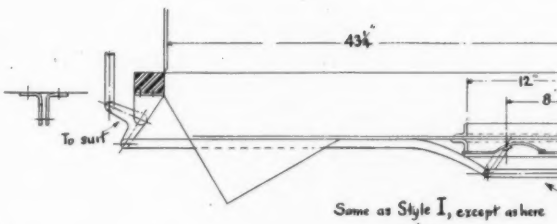


Rear View.

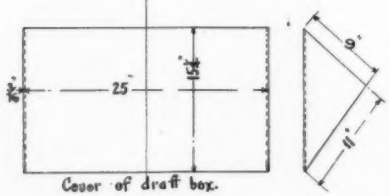




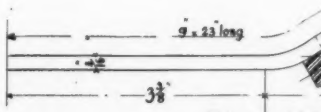
Section of draft box.



Same as Style I, except as here shown.

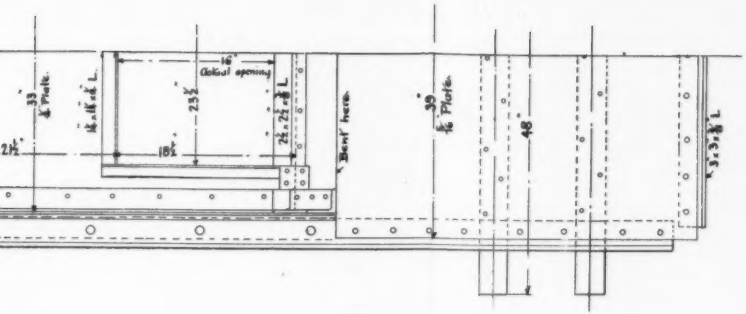


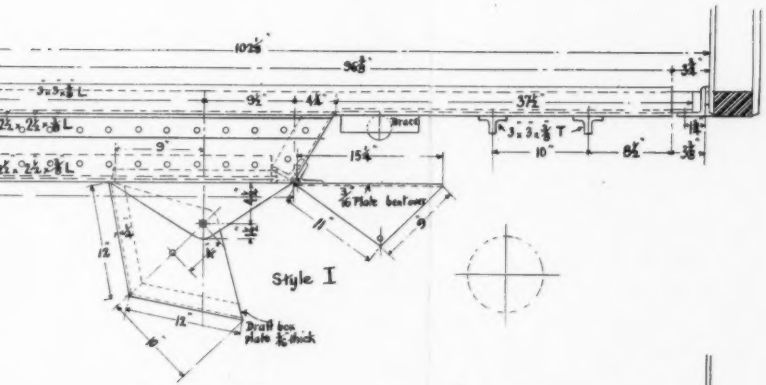
Cover of draft box.

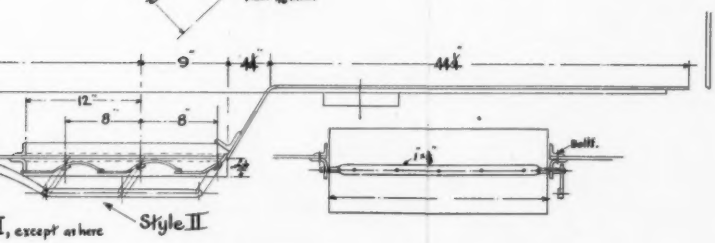


Full size detail

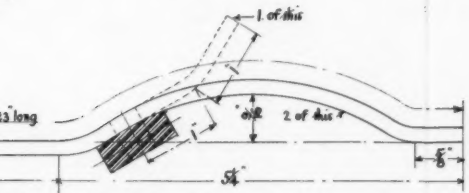
PLATE No. 3.







I, except as here
n.



Full size detail of Dampers.

The object of the latter form is to give closer adjustment of the air inlet. When engine is working hard both dampers are open, and, so far as my experience goes, I have had no difficulty in working engine to greater capacity than was possible with coal, with an absolutely smokeless fire and a fairly economical consumption of oil. When engine is stopped for any length of time the forward damper is closed entirely and the back damper opened about half way, so that with the exhaust of the air pump in stack a light, clear fire maintains the heat of the fire box and holds steam pressure.

It will be noted that all of the air admitted to fire box must pass the arch before reaching tubes so that it becomes as thoroughly mixed as is possible, and no air reaches the tubes at a lower temperature than the arch.

The shape of the arch and the force of the burner jet imparts a rolling action to the gases, and they rebound from the arch wall as far toward the fire door as the intensity of the draft will permit.

In plates No. 2 and 2*a* the burner is shown fitted at fire door, and this gives a better arrangement for admitting air.

These improvements are made possible by the shape of fire box, as will be readily seen by comparison.

To secure best results from oil fuel the proper volume of air for combustion must move as slowly as possible up to the bridge or arch wall, and after passing same, the velocity should be reduced again before passing tubes. Attempts have been made to secure a perfect mixture of air by taking the entire supply through burner port by the inducing action of burner jet, and while this makes a good arrangement for heating furnaces it gives very poor results under a boiler. A very high temperature is secured in fire box, and I have seen the furnace lining melted, but there is a poor distribution of heat through the other parts of boiler setting.

Another point that must be noted is to keep the burner jet and products of combustion moving in one general direction. In firing a burner directly against an arch or bridge wall some of the gases rebound to bottom of fire box, where, as a rule,

they are not needed, but serve only to divert the flow of the greater volume of gas from the proper direction.

Referring to the short, deep, fire box mentioned in the preceding pages, it will be seen that all the combustion chamber available is above the arch, and here a shorter time to perfect combustion of gases is given, and hence a more difficult problem to secure a smokeless and efficient fire. The arch wall cannot be moved toward the burner, for, with the amount of oil burned, from four to five feet is necessary for atomizing space. Therefore the proportion of this setting must be arranged to suit the average duty of the engine. This is done by regulation of air opening and intensity of draft. The diaphragm and nettings are taken out of the front end or smoke box of the locomotive and the "petticoat pipe" over exhaust nozzle is raised gradually until the engine meets the varying conditions of load with the least consumption of fuel. No rule can be given for height of "petticoat pipe," but on engines having from 18 inches to 20 inches diameter of cylinders, from 5 inches to 8 inches above top of nozzle will be found to be about right. The diameter of exhaust nozzles may be increased slightly over those used for coal fire.

Figure No. 2, plate 7, gives a setting used on the Babcock & Wilcox type of water-tube boiler, and here will be noted the short time allowed for forming proper mixture of gases similar to the conditions in the narrow, deep fire box of locomotive. After once reaching the bank of tubes the heat of the gases is absorbed very quickly and all aid to combustion from incandescent brick walls ceases. It is therefore necessary to perfect the combustion in the fire box without the aid of the hot combustion chamber.

This is accomplished by bringing the air into fire box just in front of burner. The action of the burner jet sweeps it along the hot paving and rolls up under the arch. At this point the action of the draft sets in and turns the current of the gases up between the tubes. During the time the gases are under the arch and being diverted by the action of the draft they complete their mixture.

I have on several occasions tried air admitted through open-

ings under arch and through a hollow arch wall, where a small proportion may be admitted with advantage. A large quantity will generally go directly into the bank of tubes without mixing and will cause smoke.

MARINE INSTALLATIONS.

In taking up the marine boiler we have two points not touched in the consideration of the locomotive or the stationary boiler, *i. e.*, forced draft and the use of air as an atomizing agent. The latter will be more fully treated under the head of burners.

In using forced draft on a coal fire, assuming the fire to be clean, every cubic foot of air has to pass an incandescent bed of coal, and the finely divided air passages secure a very perfect mixture. With oil the atomized fuel is discharged from the burner and expands into the fire box, so that there are chances, with an improper admission of air, of a poor mixture of gases. Now, if we take up the ordinary cylindrical furnace, we will see that it offers ample time for this mixture with either forced or natural draft. The burners are set, as shown in detail in plate 4, projecting into a short furnace extension, and the furnace is lined with a fire-brick ring from three to four feet long.

The low-pressure air burner does not need a baffle or "spatter wall," but will maintain its fire from heat of surrounding brick work. In short furnaces a fire-brick wall is laid up in the back connection protecting the back sheet for two feet above top of furnace. With the air taken in at the bottom of furnace extension, it is given an opportunity to combine with the atomized oil in the hot brick-lined portion of flue and the furnace beyond. An illustration of this type of furnace is shown in plate 4, which illustrates the equipment of the boilers of S. S. *City of Everett.*

There are two positive blowers driven by independent vertical engines. Only one blower is used, the other being held in reserve. The oil pumps are also in duplicate. There is a small auxiliary blower driven by gasoline engine. This blower furnishes air for one burner in each furnace, and runs under a higher pressure than the large main burners. These small burners are also connected to use steam as an atomizing agent. In starting

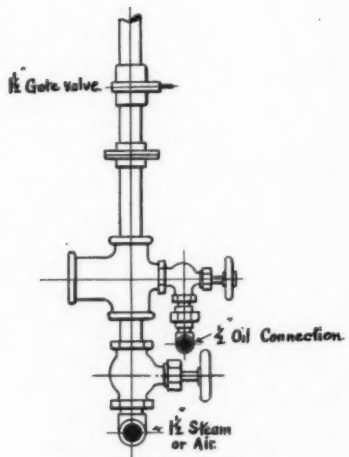
up, the gasoline engine is run until steam is raised on one boiler and the main air plant started. When lying at anchor the main blower is stopped and steam is held by the auxiliary plant, and should it be necessary to stop this before starting the main blower, the auxiliary burners can be operated with steam. The furnaces are lined 2 feet 8 inches from fire door with fire brick, and have 28 inches extension to fronts. The burners fire directly into the extensions with no baffles, there being two main burners to each furnace. The air for combustion is taken in through bottom of extension.

The application of the water-tube boiler to marine service and the firing of same with oil brings us to the comparison of the short type of locomotive fire box with the Babcock & Wilcox setting in fig. 2, plate 7. The tests of the Naval Fuel Oil Board on the Hohenstein boiler were carried out with such minute detail that an outsider would hesitate to offer any criticism.

In reading the report of the various tests it is noticed that in forcing the boiler considerable smoke was made. This may be due to the fact that a portion of the air passed through the fire box without thorough mixture, and the presence of carbon on bridge wall shows that some of the oil was deposited there in a partially unconsumed state. Carbon deposit is more often found where air is used for atomizing than where steam is used. This is probably due to the fact that the greater velocity of the steam combined with its expansive action breaks up the oil and distributes it better than the air.

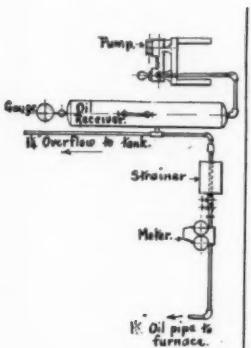
Applying the general experience of the past to the water-tube type of boiler, I would offer as a suggestion the setting as shown in plate 7, fig. 3.

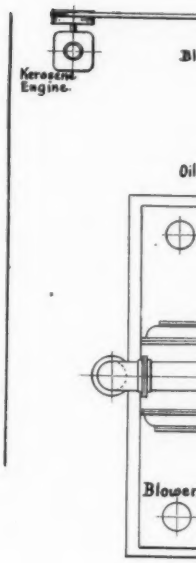
As stated above, the air may be brought in through openings near base of bridge wall or through ash-pit door. In the former instance the air receives the heat from the brick paving of fire box. A few loose brick on paving help to distribute the partially mixed gases, and the bridge wall with overhanging top gives them the rotary motion alluded to in preceding pages. The lower course of baffle brick is cut out to leave an ample opening into bank of tubes. The arrangement of baffles is a very im-

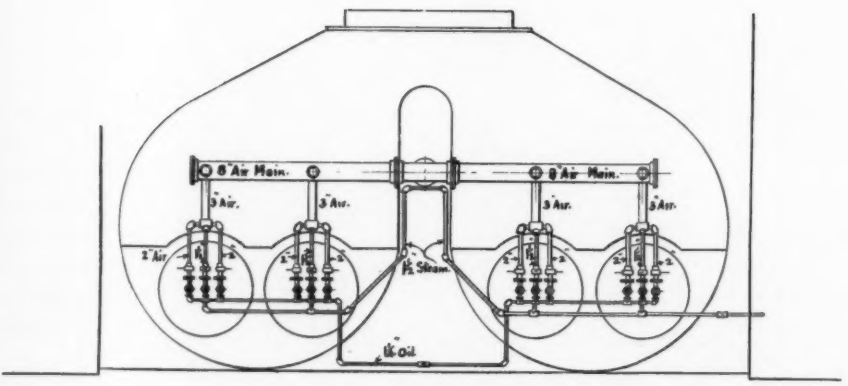


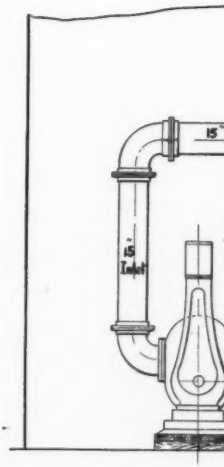
Center Burner Connection.

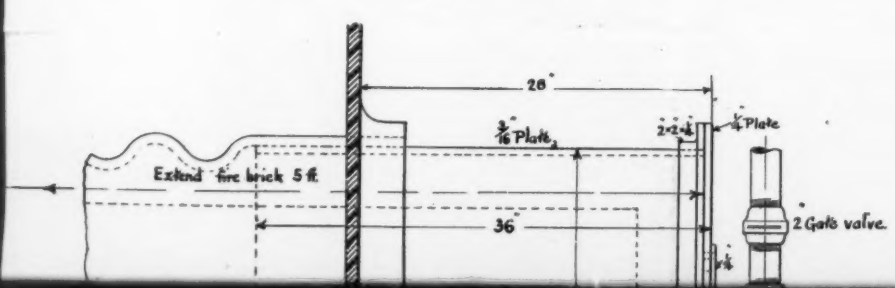
Scale 1½" = 1 ft.

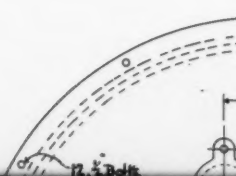


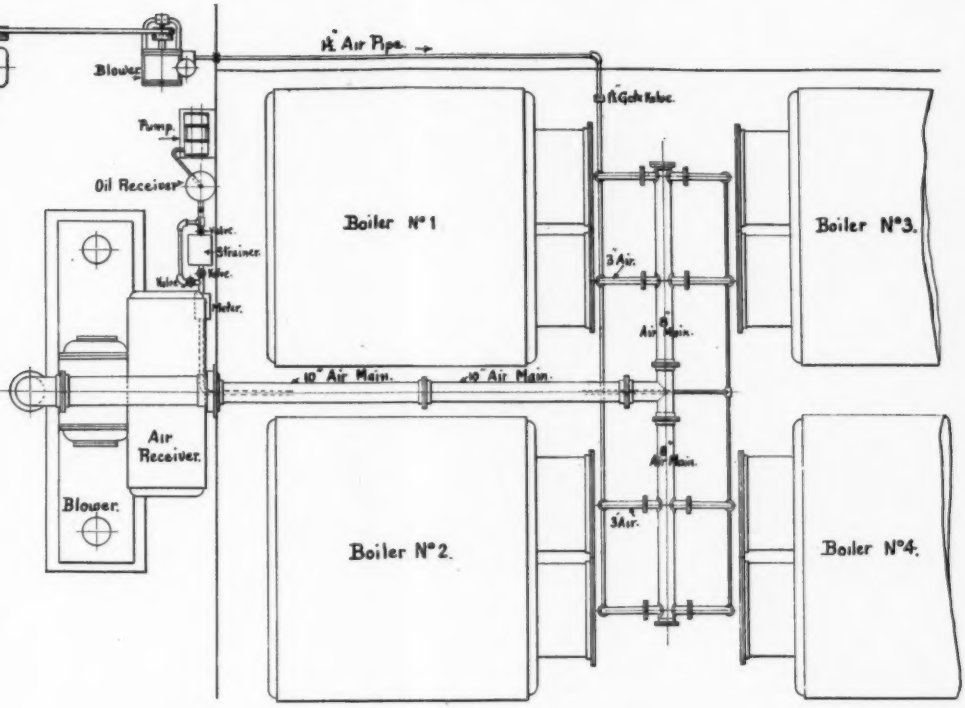


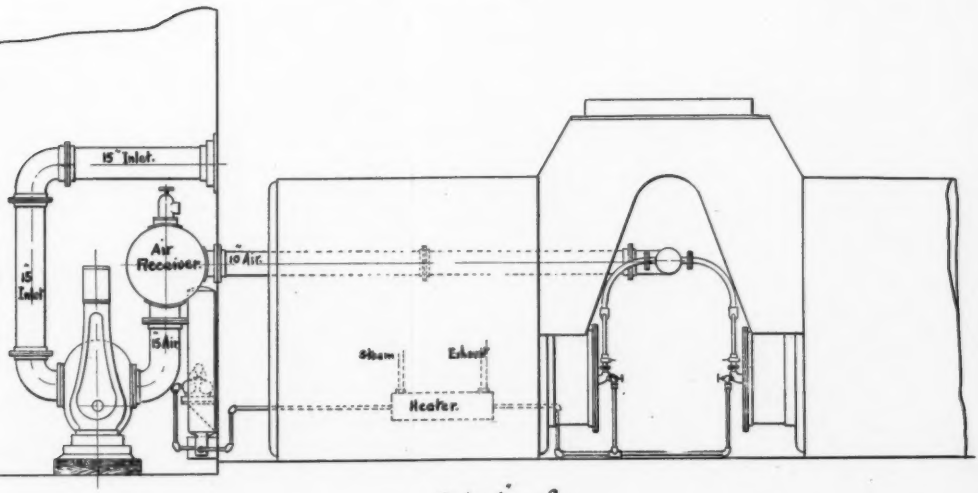




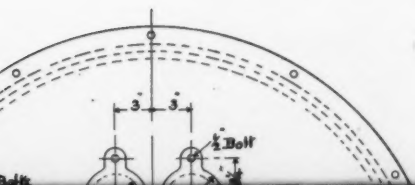


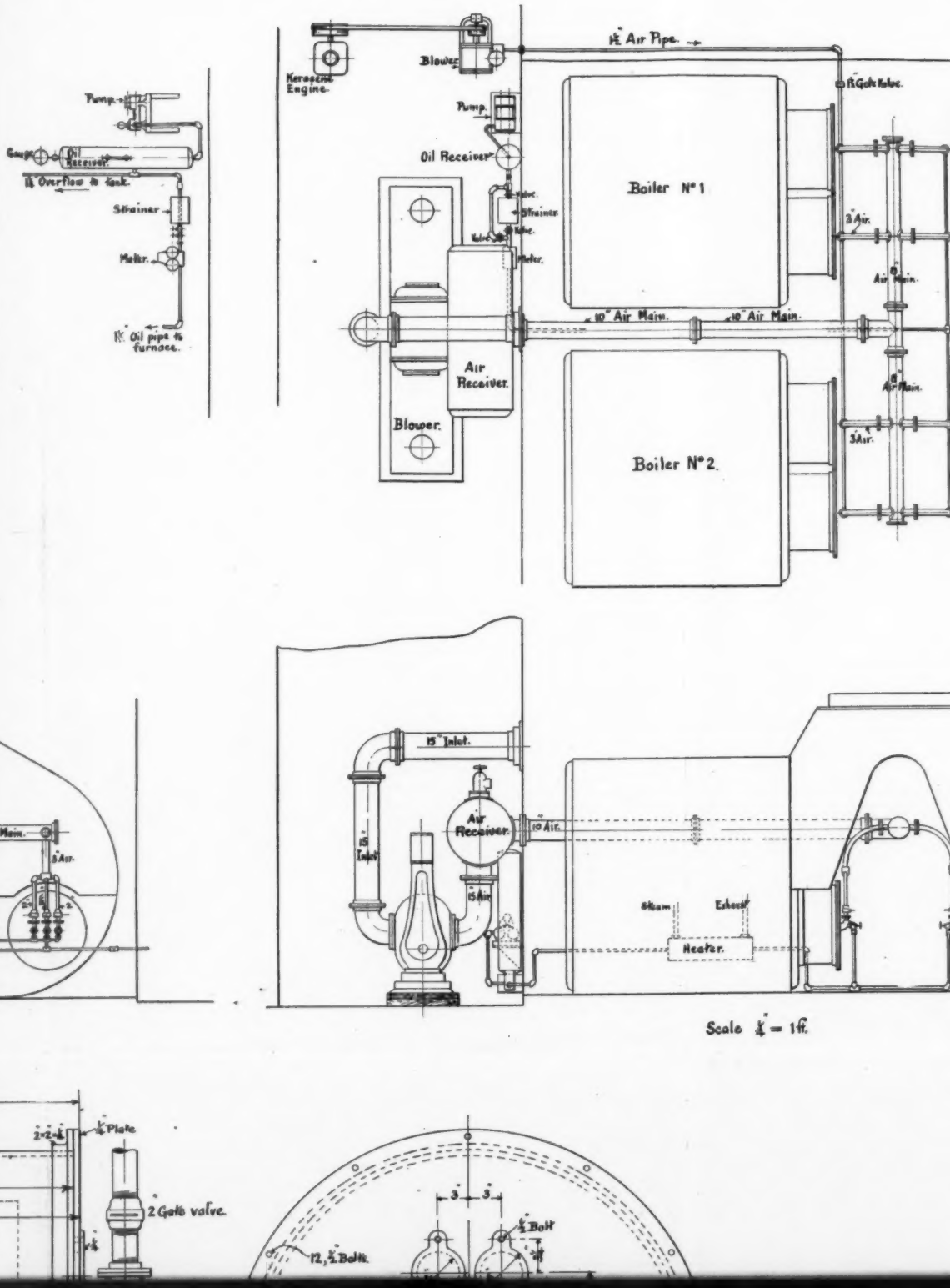


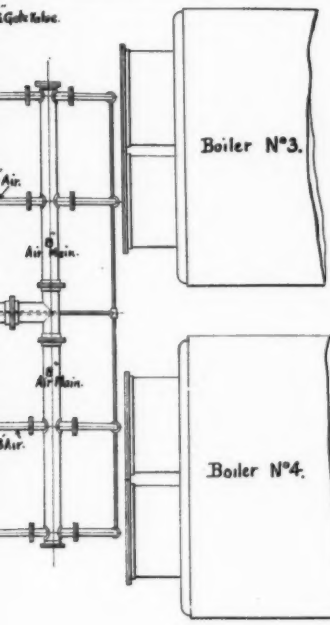

14" Air Pipe.
Blower.
Pump.
Oil Receiver.
Valve.
Strainer.
Valve.
Valve.
Meter.
Air Receiver.
Blower.
Boiler N°1
Boiler N°2.
Boiler N°3.
Boiler N°4.
1½" Cock Valve.
3" Air.
8" Air Main.
10" Air Main.
10" Air Main.
8" Air Main.
3" Air.

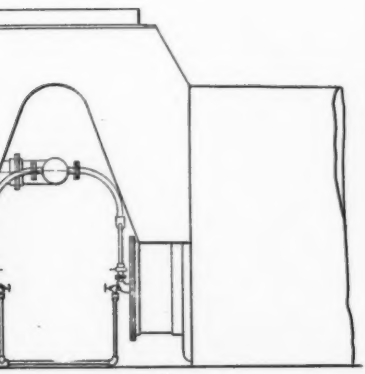

15" Inlet.
Air Receiver.
15" Inlet
10" Air.
15" Air.
Steam
Exhaust
Heater.

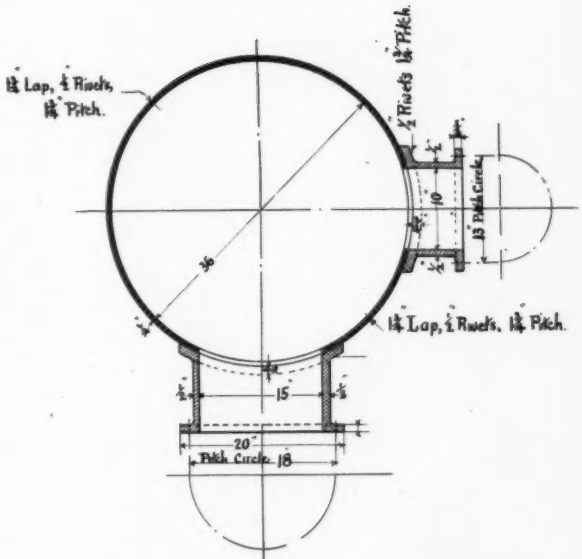
Scale ¼" = 1 ft.

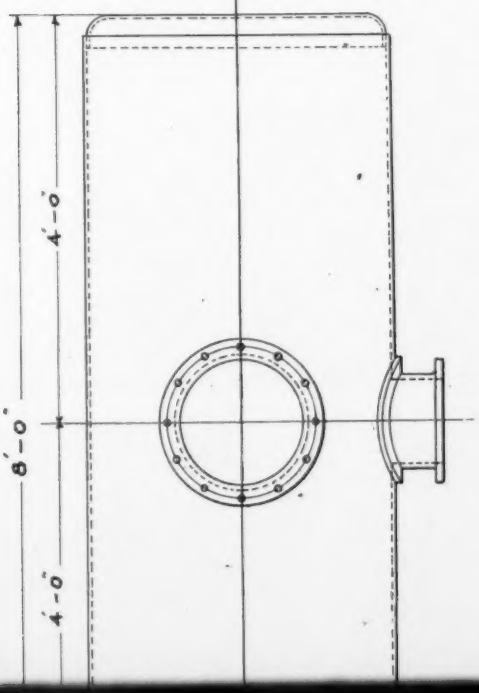

3
3
½" Bolt


Pump.
Gauge.
Oil Receiver.
1½" Overflow to tank.
Strainer.
Meter.
1½" Oil pipe to furnace.
Kerosene Engine.
Blower.
1½" Air Pipe.
1" Gate Valve.
Pump.
Oil Receiver.
Valve.
Strainer.
Valve.
Meter.
Boiler N° 1
3" Air.
8" Air Main.
10" Air Main.
10" Air Main.
Air Receiver.
Blower.
8" Air Main.
3" Air.
Boiler N° 2.
15" Inlet.
Air Receiver.
10" Air.
15" Inlet.
15" Air.
Steam
Exhaust
Heater.
Scale ¼" = 1ft.
2"×2"×¼" Plate
2 Gate valve.
12, ½" Bolts.
3"
3"
½" Bolt


Boiler N°3.
Boiler N°4.



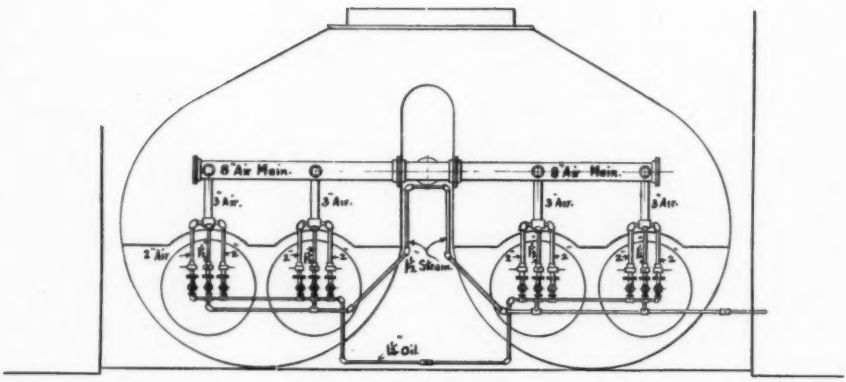

1¼ Lap, ¼ Rivets, 1¼ Pitch.
¼ Rivets 1¼ Pitch.
1¼ Lap, ¼ Rivets, 1¼ Pitch.
36
10
13 Pitch Circle
15
20
Pitch Circle 18

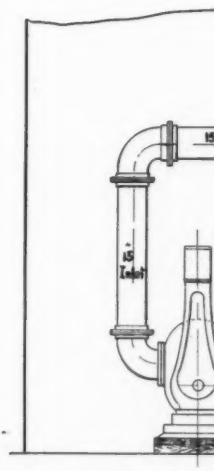

4'-0"
4'-0"
8'-0"

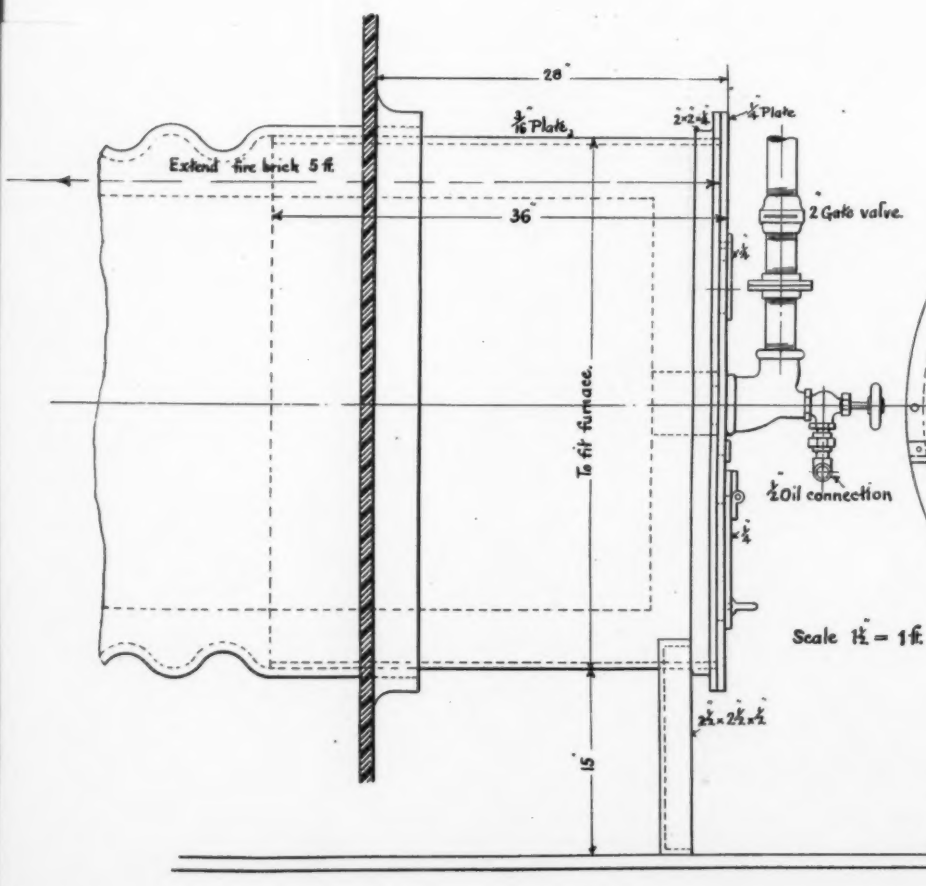
or Air.

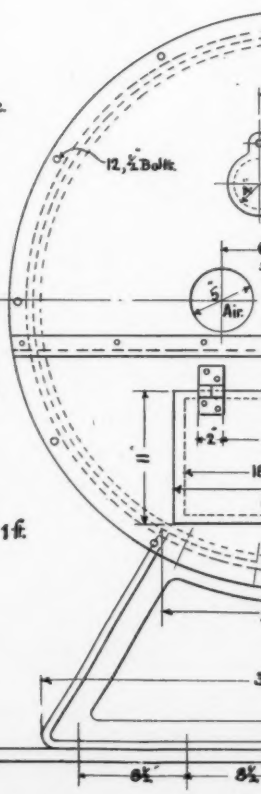
Center Burner Connection.

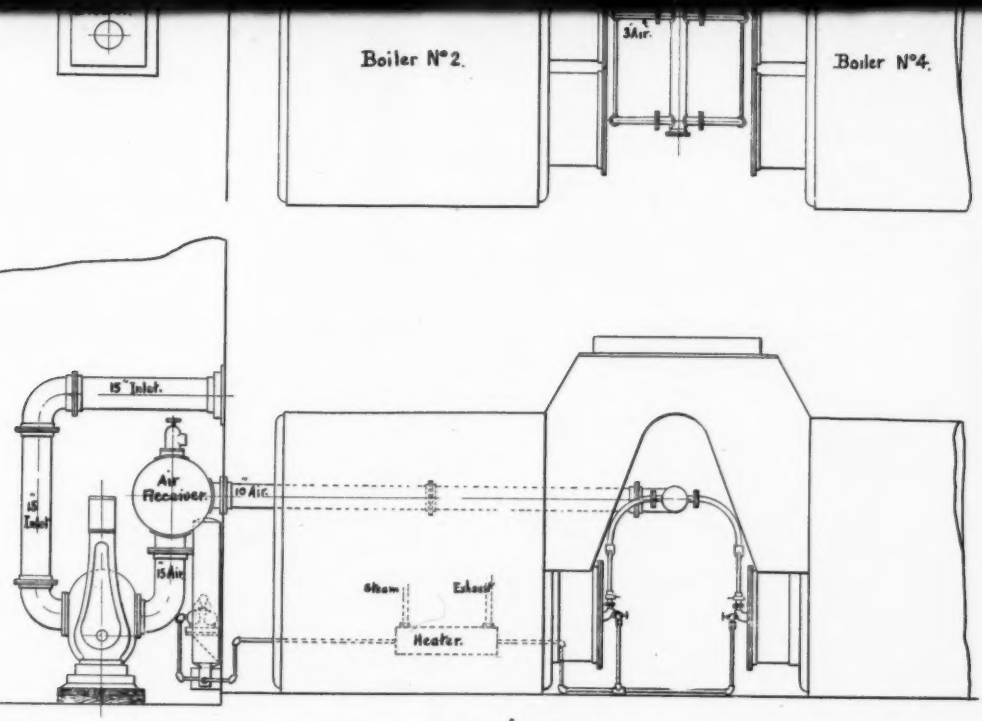
Scale 1½" = 1 ft.











Scale $\frac{1}{4}$" = 1ft.

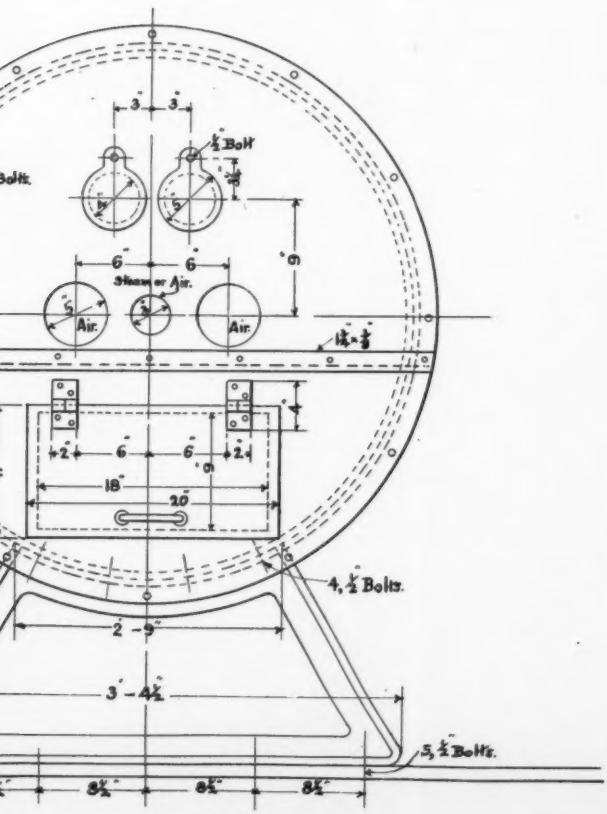
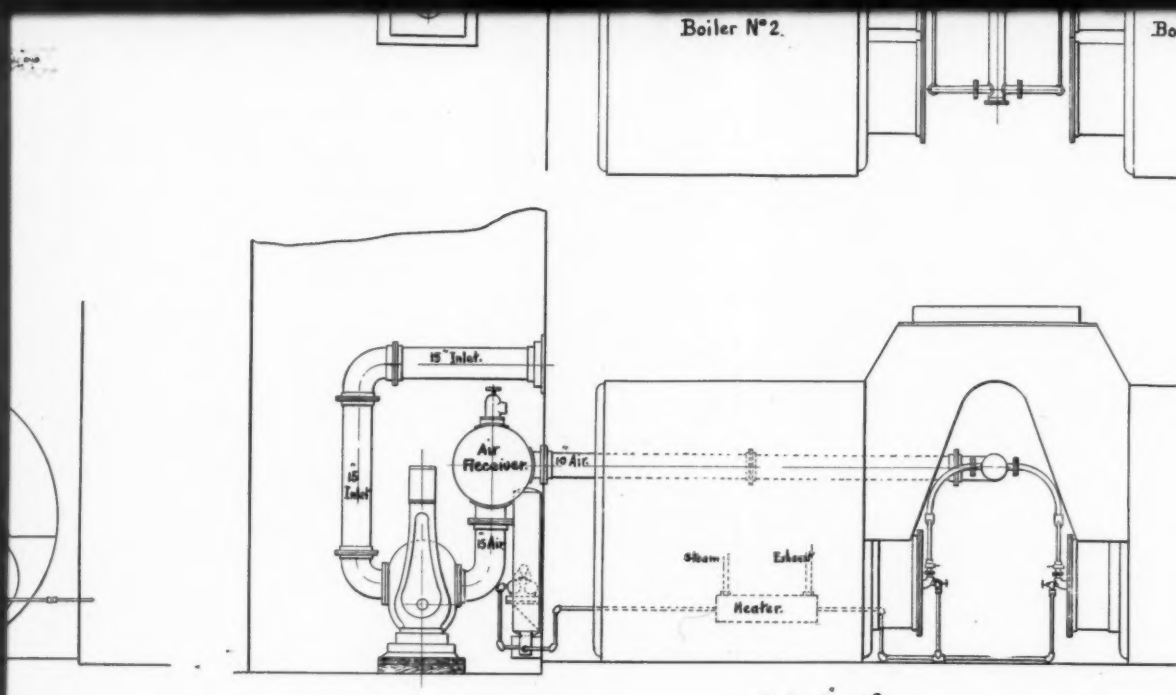
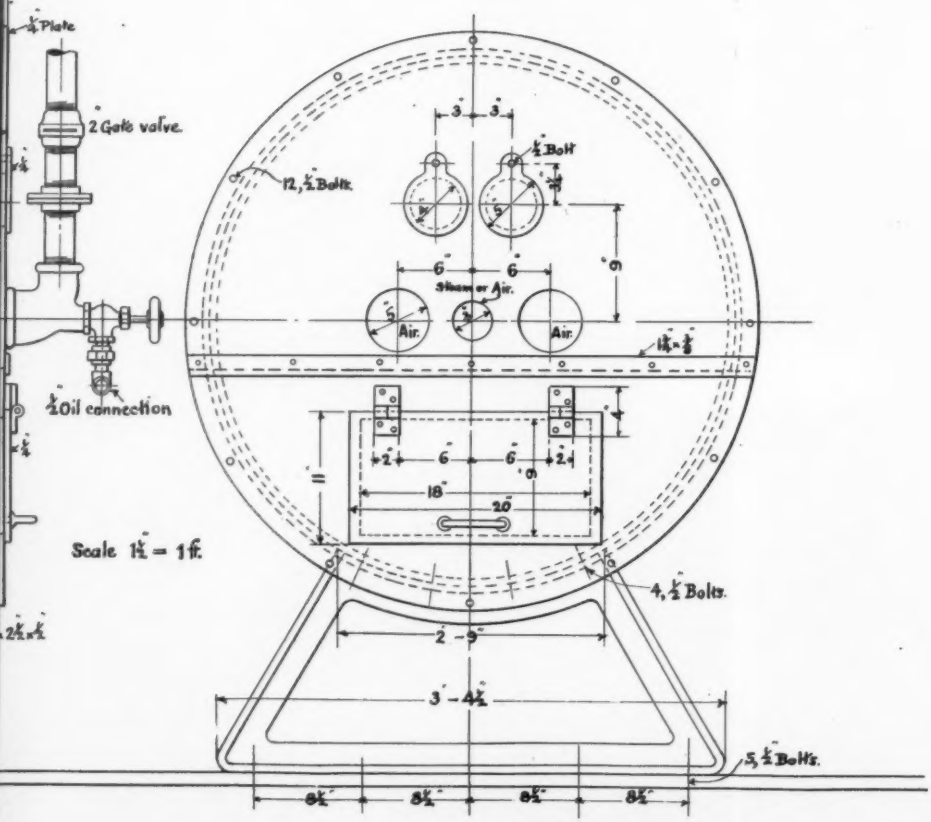


PLATE No. 4.

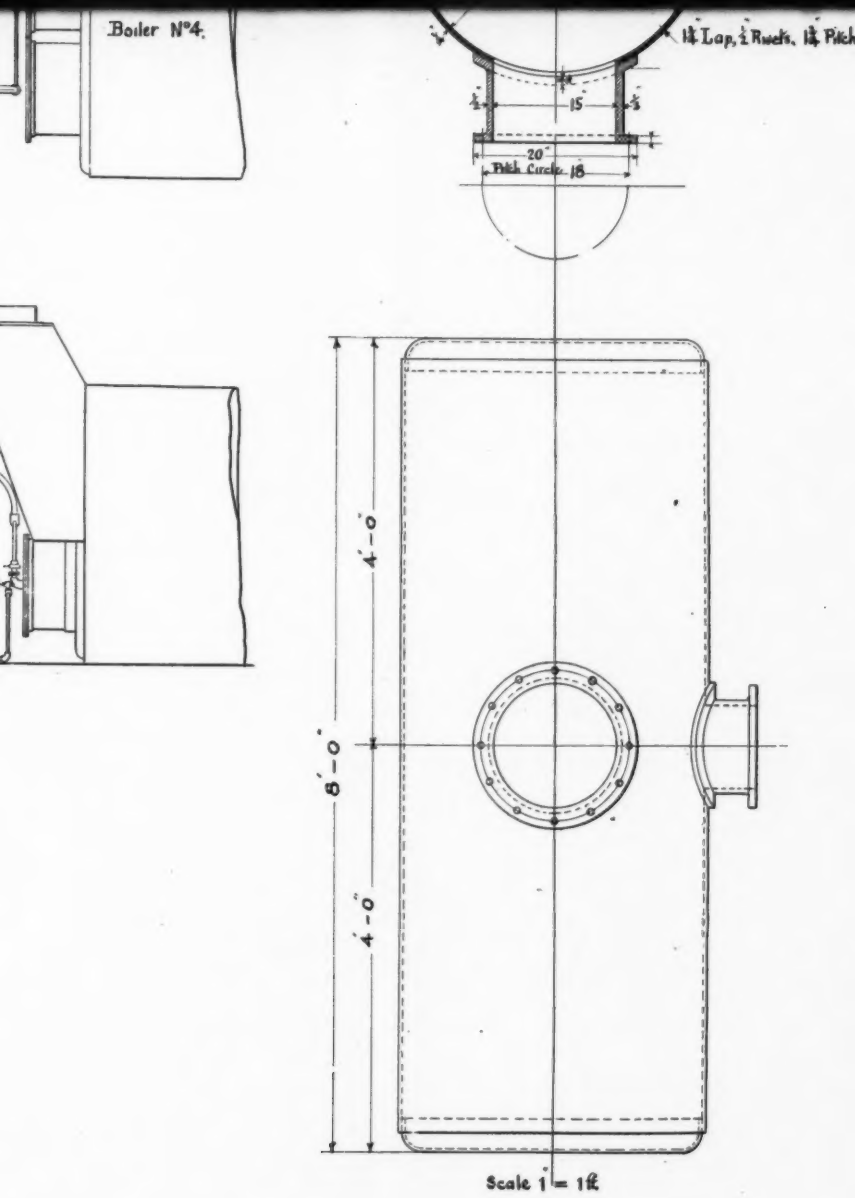


Scale $\frac{1}{4}$" = 1ft.



Scale 1½" = 1ft.

PLATE No. 4.



S. S. "City of Everett"

Fuel Oil System.

1902.

portant item and one which is properly determined only by actual tests.

BURNERS.

The fuel oil burner has furnished almost as much work for the Patent Office as the car coupler, and at the present time very few, if any, of these patents are designed in accordance with the fundamental principles of an oil burner. The simplest piece of mechanism using the least amount of atomizing agent is the best. The various schemes for superheating the atomizing agent, or converting the oil into a gas before leaving burner, do not add to the efficiency of the fuel, but, on the contrary, reduce the evaporative duty. I have never seen a fuel oil gas that would equal direct-fired oil for steam generating. In boiler firing steam is a most satisfactory atomizing agent where the loss of steam through the burner is permissible. This loss, in a good atomizer of the round-nozzle type, is from 2 per cent. to 5 per cent. of the nominal horsepower rating of the boiler. In the slot type of burners the loss is somewhat greater, but I have no detailed figures on this.

For marine or stationary boilers the burners may be set where they are easily accessible, and either one or two burners to a furnace, where furnaces are of the cylindrical type, will suffice. I do not think increasing the number of burners and decreasing their individual capacity is a good plan, for it means the use of more steam or air for atomizing, and it is difficult to get an even distribution over several burners. By some it is claimed that a closer regulation is obtained, but it must be remembered that a burner which can atomize 200 gallons of oil per hour can be cut down to from 8 to 10 gallons for light firing.

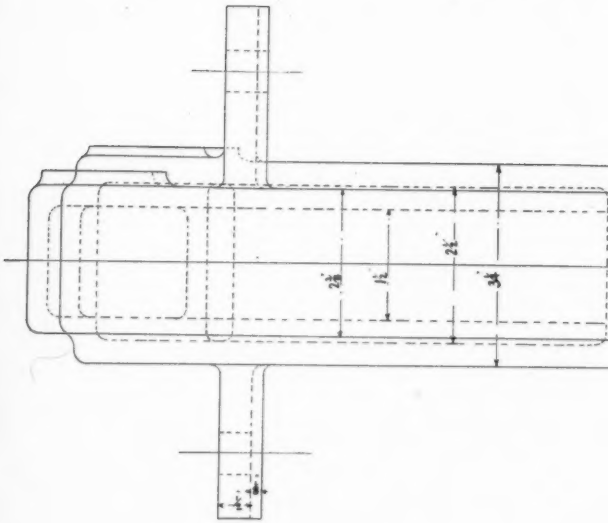
With the water-tube type of boilers having several furnace doors, from one to two burners to each door is the best arrangement. On a locomotive, where the burner is set under the fire-box ring, it is out of sight of the fireman, and therefore must be reduced to the simplest form and be free from all liability to clog. The regulation is accomplished by valves in the steam and oil supply pipe, which have stems extended up to reach of fireman. These are shown in detail in plates 1, 2 and 2*a*.

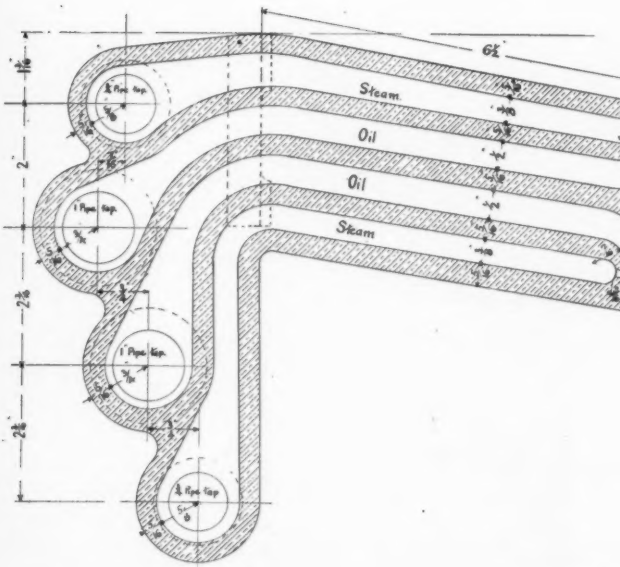
For burning a large amount of oil and meeting the necessity of getting the proper mixture of gases as quickly as possible, the slot type of burner seems to give best results. Plates 5 and 5*a* show burners of this type, designed by the writer, and used on the Boston and Maine, and Florida East Coast Railways. The drawings show burner changed to enter fire door (plates 2 and 2*a*), and the nozzle is pointed down instead of upward as in plate 1. There are really two burners in one casting, one of greater capacity than the other, so that with light loads or while waiting under steam pressure the smaller burner may be run. The small burner is large enough to be forced so as to fire engine under full load in case of accident to the larger burner. In arrangement of oil and steam passages the opening for the oil is of such size that anything passing the valve will pass the burner outlet. With the steam pressure behind the steam slot there is very little chance of an obstruction sticking. In the large burner a sufficient volume of oil is always flowing, so that there is no trouble from breaking the flow by gasifying the oil on top of steam passage by heat, and, therefore, the stream of oil is brought over the steam jet.

In the small burner, where the oil feed is generally light, the oil must fill the passage before meeting the steam jet, and this prevents the breaking or pulsating of burner, as would be the case if a thin film of oil was fed over the hot steam passage.

In the passage beyond the steam slot the expanding steam jet atomizes the oil, and as this atomization depends upon the velocity of the steam, a very good suggestion has been made by the senior member of Naval Fuel Oil Board. His plan is to proportion this passage on the lines of the nozzle used in steam turbines and thus increase the velocity. I believe this would improve the burner, but the nozzle should not extend over 1½ inches from the steam slot. On heavy work this burner has atomized at the rate of 300 gallons of oil per hour, and while waiting for trains the small burner has been run at from 8 to 10 gallons per hour.

Much time and money have been wasted in constructing burners with a view to decomposing the steam and gaining the heat from





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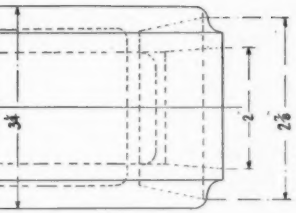


Duplex Fuel Oil Burner

for Locomotive

Fire door type. April 13th 1902.

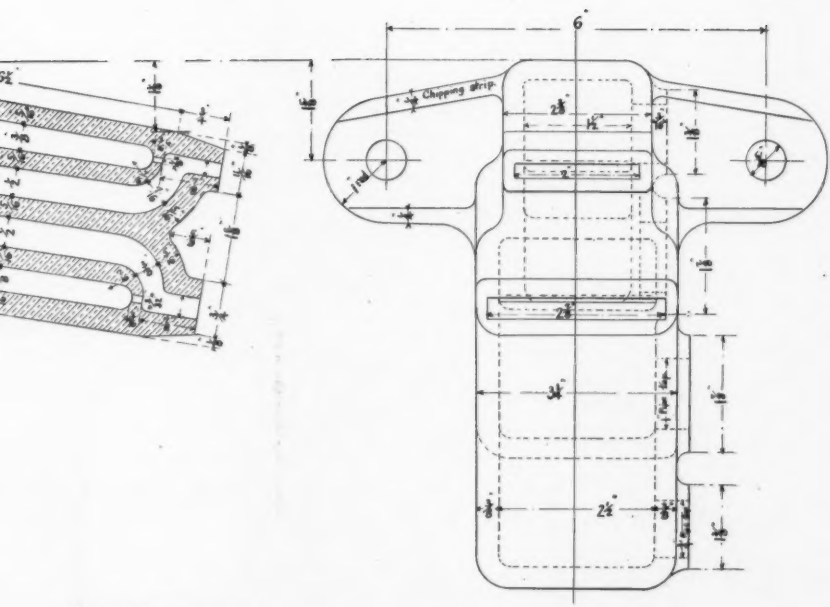
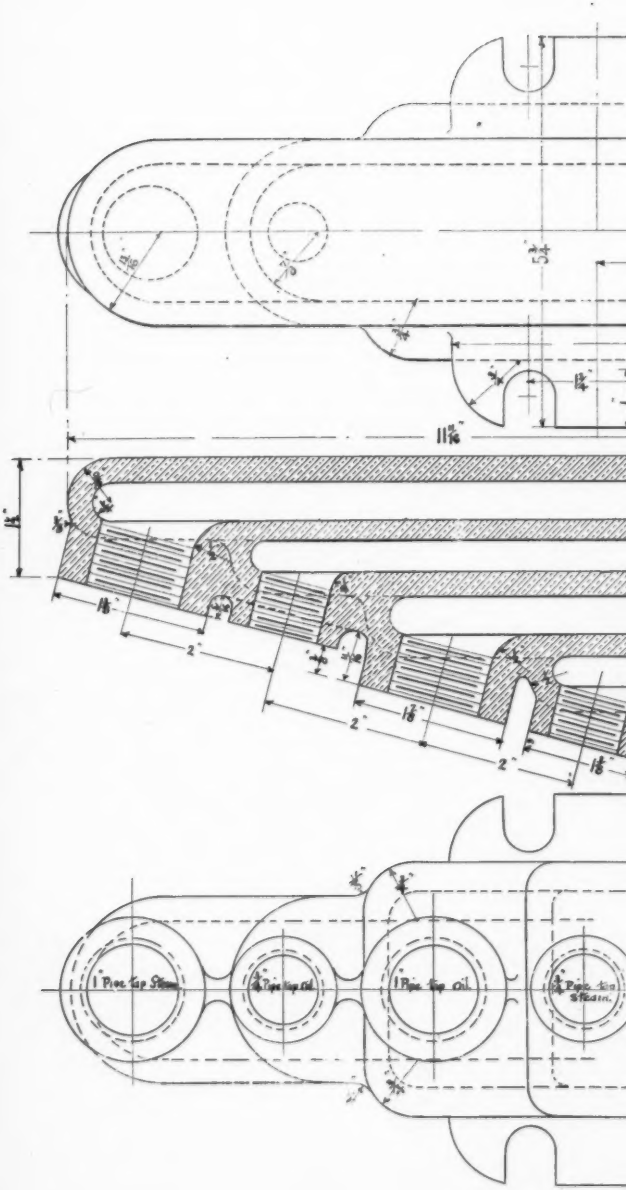
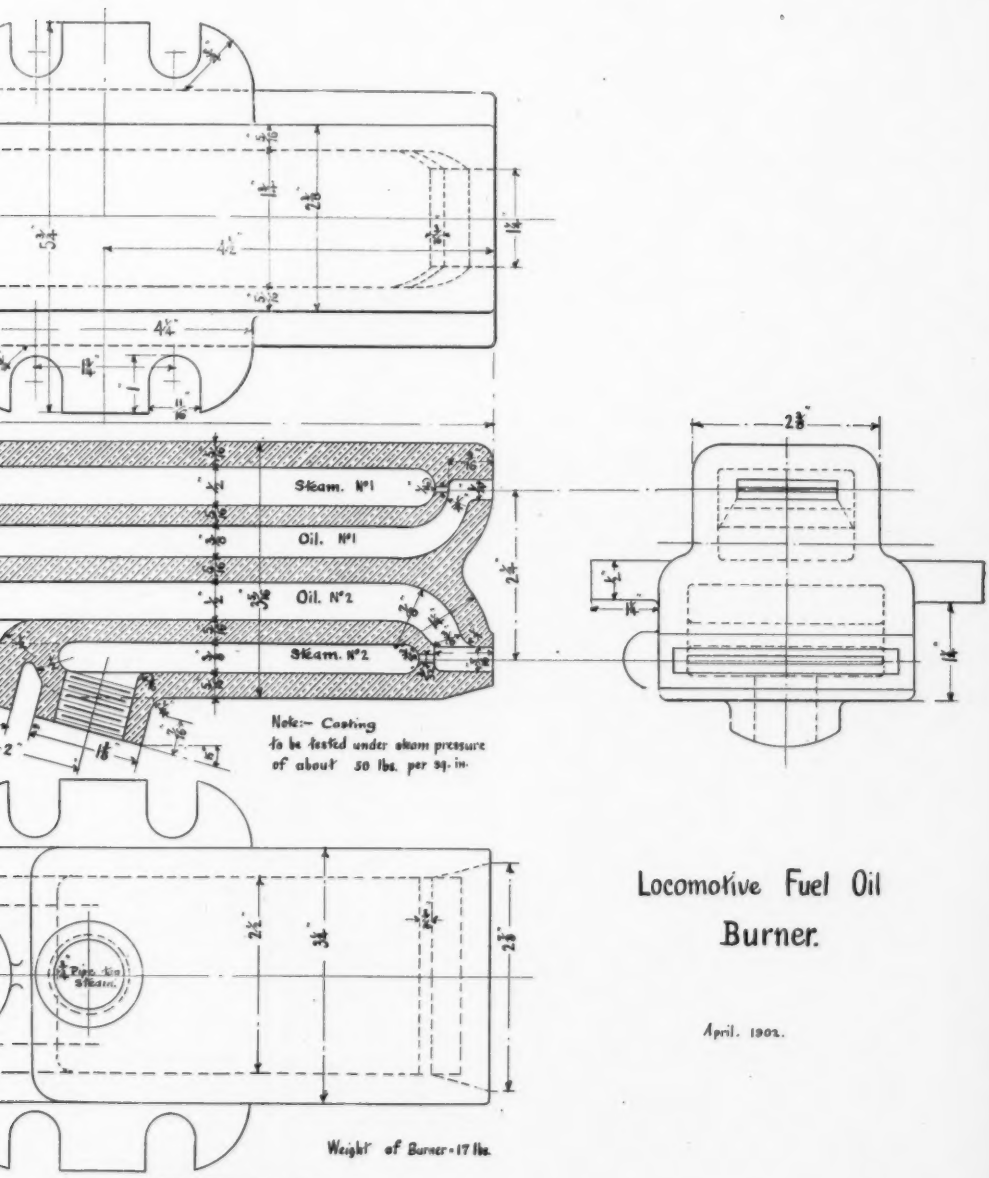


PLATE No. 5.


11 15/16"
2"
2"
2"
1 Pipe Tap Steam
1 Pipe Tap Oil
1 Pipe Tap Oil
1 Pipe Tap Steam



Locomotive Fuel Oil Burner.

April. 1902.

Weight of Burner - 17 lbs.

PLATE No. 5a.

the burning hydrogen gas. It only need be said that the heat expended in this decomposition is hardly realized in the burning of the hydrogen, so that there is no gain from this source. It is doubted very much if any decomposition takes place in a boiler furnace, but it is thought that the steam distributes the gases better than any other atomizing agent. The steam certainly takes a portion of the heat from the furnace, and in comparing results from atomizing by steam with those obtained from a low-pressure (1 to 5 pounds) air atomizer I have found the air to be from 10 to 15 per cent. more economical in fuel. When it came to a question of forcing, the boiler could be run to 25 per cent. greater capacity with steam than with air.

There are several good burners in the market and many more which are simply mechanical monstrosities. Some burner enthusiasts are often heard to claim that they could save from 25 to 50 per cent. of the oil used by any other burner. To show the unreasonableness of such claims it is enough to direct attention to the fact that with a properly set stationary boiler 15 to 15½ pounds of water may be evaporated from and at 212 degrees per pound of oil, containing, say, 19,000 B. T. U. per pound. With the losses due to stack temperature and radiation, 80 per cent. of the theoretical evaporative duty of the fuel is about as good as we can get. Taking the theoretical evaporation of our oil at 19.6 pounds water per one pound oil, we have 15.6 pounds water evaporated, which is very close to the result stated, the loss being due entirely to stack temperature and to furnace setting. I have seen very few burners which would not atomize well enough to give 13 pounds evaporation, and with the majority 14 to 15 pounds is the rule. Now, if the inventor who is going to save 50 per cent. can evaporate even 13 pounds of water with ½ pound of oil, he has certainly equalled the solution of the problem of perpetual motion.

In plate 6, is shown a convenient way of making up a burner for experimental work. Figure 1 is a general drawing of burner which is constructed of standard pipe fittings. The atomizing agent is admitted through pipe A, and the oil through B. These connections are made in line with each other so that they form

Fig-2

Fig-1

Fig-3

Fig-4

Fig-5

0 1" 2"
SCALE-INCHES

PLATE No. 6.

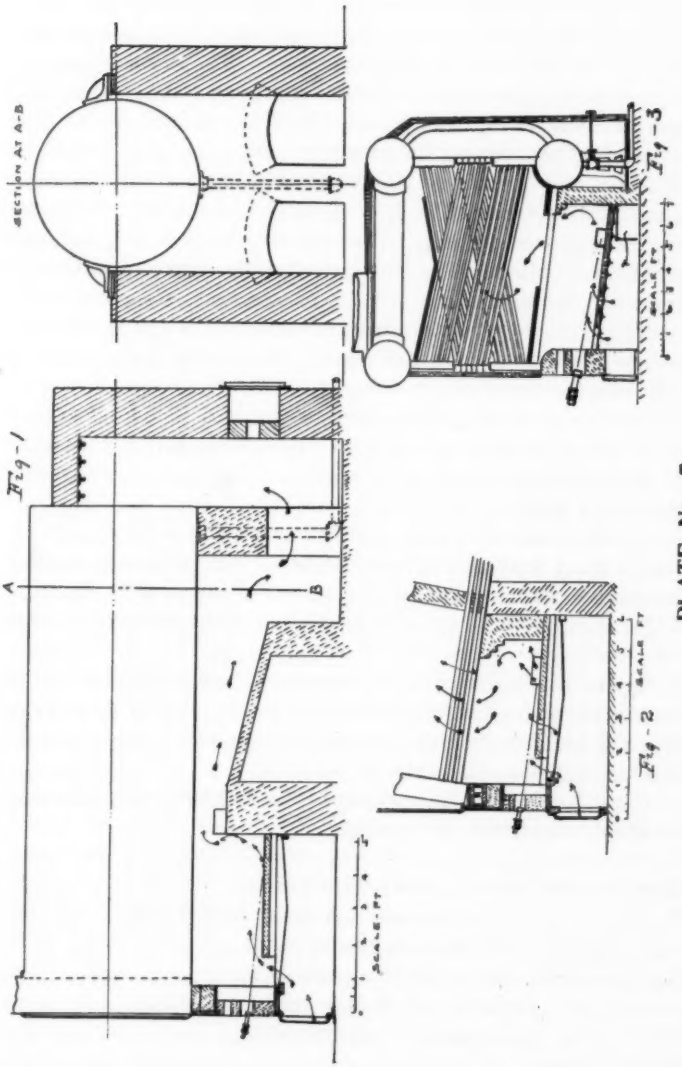


PLATE No. 7.

trunnions for elevating or depressing the end of burner. This is an important feature, as a slight deflection of burner jet may make a vast difference in the combustion. The size of atomizing pipe is usually $\frac{3}{4}$ to 1 inch when steam is used, and $1\frac{1}{4}$ inches with air. The oil passage is $\frac{1}{8}$ pipe inside of burner and $\frac{3}{8}$-inch pipe outside. The opening in discharge end of oil pipe is $\frac{1}{8}$ inch diameter, and the cap on atomizing pipe has a taper hole from $\frac{3}{8}$ inch at the large end to $\frac{3}{16}$ or $\frac{7}{32}$ inch on small end. This cap may be adjusted to proper distance from end of oil pipe and locked by jam nut. The oil pipe is held in central position by three set screws or pins.

Figure 2, shows connections for burner, the distance between unions being about one inch greater than width of fire door, so that when removed the doorway is left clear.

Figure 3 shows air burner with opening in air pipe from $\frac{7}{16}$ inch to $\frac{5}{8}$ inch diameter, used with air pressure from 1 to 5 pounds. In this case the oil pipe may be adjusted to proper distance from atomizing outlet.

Figure 4 is another form of same burner, where the oil valve is seated in oil-discharge tip, and the stem extends through stuffing box in the other end of pipe, or in place of the plug D, shown in Fig. 1. Either the plug or stuffing box may be removed to clean oil pipe.

Figure 5 is a tip used for low air and oil pressures, from 5 to 16 ounces air, and a head of 10 feet on the oil. The oil tip projects about $\frac{1}{4}$ inch beyond the atomizing cap, and oil drops into the apex of cone formed by the air currents.

In the locomotive "slot-type" burner in plate 5, the following were the proportions of openings:

Small burner:	Steam outlet, square inch, . . .	.076
	Combined oil and steam, square inch, .	.3125
	Oil passage, square inch, . . .	.656
Large burner:	Steam outlet, square inch, . . .	.195
	Combined oil and steam, square inch, .	.9375
	Oil passage, square inches, . . .	1.25

The Baldwin Locomotive Co., in an interesting description of their oil burning locomotives, catalogue No. 37, gives as a rule for determining the width of a slot burner, "Width, $\frac{1}{3}$ inch for each cubic foot of cylinder volume, or width of burner in inches equals *volume of both cylinders in cubic feet* divided by 3; or, that 1 inch of burner is sufficient for 600 square feet of heating surface."

Atomizing by air pressures from 15 pounds upward means the use of an air compressor with a consequent expenditure of power and sacrifice of floor space. For forge or small furnace work compressed air may be used with advantage, as it concentrates the heat and makes a very clean fire. For boilers this concentration of heat is generally destructive to the tubes or sheets directly over burner, and when forced the fire will often injure the brick lining of furnace. With air at 15 pounds and above, a certain amount of air is taken in at burner port by action of jet, and this with the supply for atomizing will be enough to support combustion, when used for forge or heating furnaces. The above reasons leave the air compresser out of consideration for use on marine boilers, and the loss of fresh water through burner is a strong argument against steam. Therefore it appears that air from a positive blower is the atomizing agent best adapted to this service.

In selecting a positive blower for this purpose, it is well to make it of ample capacity and to reduce its speed well under the normal rating. When the main air pipe is 8 inches or over in diameter and has a run of from 10 to 12 feet to burner branch, this will furnish sufficient receiver capacity.

Oil should be fed to burners under a steady pressure, and for many years a standpipe from 10 to 15 feet above burners with an overflow at this height back to storage tank was a most satisfactory method. The pump was run so as to deliver more oil than was used by burners, the surplus returning through overflow, and a constant head was maintained. When the distance to burners did not exceed 100 feet and when storage tanks were below burner level, this arrangement worked very well. During recent years the use of heavy oils and the longer distance

for delivery has made the pressure system the best means of feeding burners. This is illustrated in plate 8, but it may be well to add that it is always best to place the oil pumps below the level of the reservoir so that any gas may be collected here. The pressure is regulated by the relief valve, and any surplus pressure blows back to storage tank. The quick-opening valve

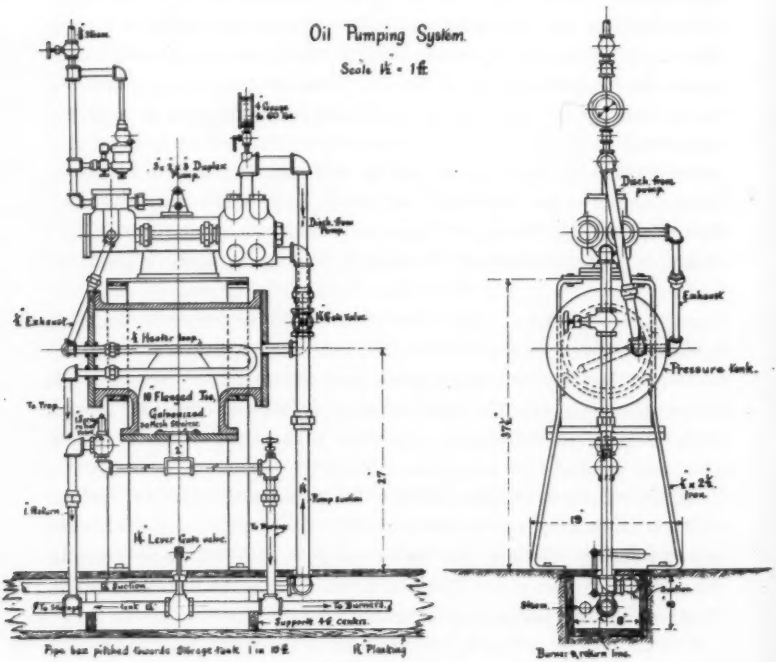


PLATE No. 8.

serves to drain system back to storage and stop all burners in case of emergency.

There are many opinions as to the heating of oil to get best results. So far as my experience goes, from 90 to 120 degrees Fahrenheit at burner will render any of the fuel oils sufficiently limpid to atomize readily. This heat is best applied in reser-

voir of pressure system, but oil must be kept warm by parallel steam line if the distance to burner is long enough to cause a loss of temperature.

PRESSURE ON OIL.

The amount of pressure to use on oil depends upon the air pressure at burner. When from 1 to 5 pounds air pressure is used, from 15 to 30 pounds on the oil will be found to be about right on ordinary nozzle-type burners. I think that under forced draft this air pressure may be increased, say 25 per cent. above these figures, but it is a good plan to keep the oil pressure under 50 pounds if possible.

On a locomotive, with burner below floor of cab the oil tank in tender will supply burner by gravity, but I have found that from 5 to 10 pounds air pressure (from brake reservoir) insures the steady feeding of burner when oil level is low in tank.

On board a vessel the storage tanks are governed by the space available. They should be placed so that any leaks may be detected from the outside and all pipe connections should be through top. The connections should be made so that tanks may be used independently of each other. Where foot valves are used on suction pipes the suction should be arranged so as to be drawn up through the top of tank in case they need inspection or repairs. The ordinary reduced fuel oils at 60 degrees contain but little gas, but under heat and agitation some gas will be liberated. This should be taken out at the highest point in tank through a vent pipe, and this pipe carried from 10 to 12 feet above deck level. When it is practical these may be run up alongside of a ventilator or smokestack. The top of vent pipe should be covered with a disc of 30-mesh wire gauze, and protected by a conical weather cap.

The filling connections to tank should be led into a main pipe line so that tanks may be filled independently. The main line should have outboard connections so that oil may be received on either port or starboard side, or forward or aft. Strainers in the suction line should be large enough to let the oil move slowly

through them. They should be at least four times the area of the suction line in which they are placed. They should be "by-passed" and be easily accessible for cleaning.

In arrangement of regulating valves it is well to avoid complication. The oil supply should be regulated at each burner, and each burner should be fitted so that it can be removed without any interference with the other burners. A main shut-off valve should be placed in oil line, so that the entire oil supply can be shut off instantaneously. This valve should be of the lever pattern.

MANIPULATION OF BURNERS.

The operation of an oil burner is very simple. In starting, very little atomizing agent is turned on. A handful of oily waste ignited and placed on paving in front of burner, and the oil turned on until it sprays on to the burning waste. As soon as the oil is ignited the oil or steam valve is opened slowly until the fire clears. Then more oil is admitted and cleared by more air or steam. When the boiler is carrying its load with the draft doors and stack damper opened as little as will give proper circulation of gases, there should be just enough atomizing agent turned on to show a clear flame where it passes the bridge wall. Every particle of air or steam used above this amount means oil wasted. In cutting down a fire to meet a decreasing load, the air or steam is turned off until the fire appears thick and cloudy at bridge wall, and the oil is then reduced until fire clears.

I have never found any advantage in using a mixture of steam and air in the burner, and the atomizing is best done by using one or the other of these agents alone.

RECORDS OF TESTS.

In tests on the Hohenstein boiler, the large amount of water evaporated per square foot of heating surface and high stack temperatures would naturally indicate a low evaporative duty. Still, judging from the average evaporation from and at 212 degrees it seems that very good results were obtained. Averaging the evaporation from and at 212 degrees, and the water

evaporated per hour for the fourteen oil-burning tests and the seventeen coal-burning tests, it appears that the oil evaporated approximately 25 per cent. more water per pound of combustible and 8 per cent. more water per hour.

On a locomotive it is extremely difficult to obtain an accurate evaporative test when running on the road, and the only figures I have been able to secure are for short stretches between water stops. From an average of a number of these I find that on heavy freight service, at speeds of from 12 to 15 miles per hour, with engine hauling its rated tonnage, about 12 pounds water per pound oil from and at 212 is the approximate evaporation. On passenger runs of 35 miles per hour and above, 13½ to 14 pounds is realized. The hardest runs I have fired are those on level sections running at high speed. Under these conditions the cut-off is very short, and the draft in the narrow, deep, type of fire box is hardly sufficient to support combustion of the necessary quantity of oil for carrying the load.

The following are some records of locomotive tests made by the writer during 1901–'2.

Record of Boston & Maine Locomotive Fuel Oil Installation.—The engines using oil were of the consolidation type, the general dimensions given below. Three were of the Baldwin Vauclain compound type, having the following cylinders: two high-pressure, 15 inches diameter; two low-pressure, 25 inches diameter; stroke, 24 inches.

These engines worked very well, but after fitting up one of the same type with simple cylinders, 20 inches diameter by 24 inches stroke, it was found possible to force this engine to greater capacity than the compound, and therefore this one was selected for making the road test.

The reason for securing greater capacity is due no doubt to the fact that the terminal pressure in the simple cylinder is higher than in the compound, thus giving a greater vacuum in front end and fire box, and consequently more air to support combustion.

At the same time I have not been able to find any economy from the compounds, by comparing their oil records with that

of the simple engine, covering a period of several months. The compounds were difficult to keep tight, so far as the piston-rod and valve-stem packing was concerned, so this may partly account for the lack of economy.

The diameter of exhaust nozzle in the simple engine was $4\frac{3}{4}$ inches, while in the compound $4\frac{1}{4}$ was the largest size that could be used.

Engine No. 1,068, B. & M., built by Rhode Island Locomotive Works in 1886; rebuilt by Keen Shops, B. & M., 1901; consolidation type; eight drivers, 57 inches in diameter; weight on drivers, 120,000 pounds; diameter of cylinders, 20 inches; stroke, 24 inches:

Total weight of engine, pounds,	141,000
Diameter of boiler shell, inches,	64
Number of tubes,	285
Diameter of tubes, inches,	2
Fire box, length, inches,	$102\frac{1}{8}$
width, inches,	$41\frac{1}{4}$
height, inches,	60
Total heating surface, square feet,	1,865.23
grate area, square feet,	29.25
Diameter exhaust nozzle, inches,	$4\frac{3}{4}$
Water capacity of tank, gallons,	3,600
Oil capacity of tank, gallons,	1,050
Steam pressure, pounds,	200

Florida East Coast Engine No. 42, built by Schenectady Locomotive Works, August 17, 1899; six 63-inch drivers, four truck wheels; diameter of exhaust nozzle, $4\frac{5}{8}$ inches:

Diameter of cylinders, inches,	18
Stroke, inches,	24
Weight on drivers, pounds,	82,500
Total weight, pounds,	113,000
Diameter of boiler, inches,	58
wagon top, inches,	66
Length of fire box, inches,	$72\frac{3}{16}$
Width at top of side walls, inches,	$32\frac{1}{2}$

Height, bottom of ring to crown sheet, inches, .	80
Two hundred and fifty 2-inch tubes 12 feet 8 inches long.	
Heating surface, tubes, square feet, . . .	1,500
fire box, square feet, . .	140
total, square feet, . . .	1,640

In railroad service the basis for estimated fuel consumption is the ton mile, although some roads base their figures on engine miles. Each engine is allotted a fixed tonnage to haul over the various divisions, these tonnage ratings being highest on the level sections and lowest on the portions of the road having heavy grades. For example, No. 1,068 is rated at 1,000 tons going from Mechanicsville, N. Y., east to East Deerfield, Mass. Over this same division west bound the rating is 600 tons.

In regard to the temperature of front end, I have no accurate figures, as these temperatures have not been recorded; but during the time I was with the engine the heat in front end, so far as we could observe, was not greater than that of the coal burning engine.

While the figures may not be of service for comparison with marine boiler work, it may be of interest to note the work done with coal and oil as a fuel on these locomotives. In each case the engine had its full rated tonnage to haul, and a thirty days' run was taken for the record. On the Florida East Coast Railway, where the road was level, 6¾ gallons oil was burned per engine mile; oil weighed $7\frac{55}{100}$ pounds per gallon. The same work with Tennessee coal for fuel resulted in 19.6 miles run per ton of coal of 2,000 pounds. Under these conditions 132.3 gallons oil equaled a ton of coal.

The same engine on freight service, with a heavier load at lower speed, showed 10.6 gallons per mile run, and on coal 13 miles per ton, or 131.8 gallons oil per ton coal. On the B. & M., on the Hoosac Tunnel helper, running double head with coal-burning engine, up grade 42 feet per mile, and returning light, engine used 11.45 gallons per mile. Oil weighed 7.75 pounds per gallon. Same engine burning coal ran 12.25 miles per ton of 2,240 pounds, and, in this service, 140.26 gallons of oil equaled one ton of coal.

In this last the engines were loaded as nearly equal as could be determined from freight records.

The following is the coal and oil record of engines No. 1,074 and No. 1,068 of the Boston & Maine R. R., on trains No. 207 and No. 298, between Mechanicsville, N. Y., and East Deerfield, Mass., eighty-five miles per trip:

Engine No. 1,074.—Coal; 23 trips.		Engine No. 1,068.—Oil; 38 trips.	
Total.	Average per trip.	Total.	Average per trip.
Cars hauled, 626	27.2	Cars hauled, 1,079	28.39
Tons hauled, 17,982	781.8	Tons hauled, 30,481	802.21
Engine miles, 1,955	85	Engine miles, 3,230	85
Car miles, 53,210	2,313.5	Car miles, 91,715	2,413.5
Ton miles, 1,528,470	66,455	Ton miles, 2,590,885	68,181
Pounds coal burned, 295,075	12,829.3	Gallons of oil, 33,700	886.84
		Pounds of oil, 260,164	6,846.4
		(7.72 per gallon.)	
Pounds of coal per engine mile, 150.9		Gallons of oil per engine mile, 10.43	
car mile.... 5.55		Pounds of oil per engine mile, 80.55	
ton mile.... .193		car mile..... 2.84	
		ton mile..... .100	
155.04 gallons per ton of coal.			

In conclusion, it may be stated that on the locomotive it was always possible to drive the engine to greater capacity with oil fuel than with coal, and with a smokeless fire. I see no reason why this cannot be done as well in the marine service, and with the work continued along lines following the Hohenstein boiler tests the proper proportions for furnace and boiler settings will be found.

In a locomotive from 15 per cent. to 25 per cent. of the coal is lost in smoke, unburned gases and cinders, which go out of stack by reason of sharp exhaust, and there is also a loss of fuel through grates.

The accompanying photograph shows No. 1,068 Boston & Maine engine "double-heading" with a coal-burning engine. The train is approaching the Hoosac tunnel, and the oil-burning engine (in front) is hauling something greater than the rated tonnage.

A glance at the smokestacks of the two engines shows what can be done with oil in securing a smokeless fire with an engine working hard.

THE VOYAGE OF H. M. S. *GOOD HOPE.*

[From "Engineering," of London, January 30, 1903.]

The recent voyage of H. M. S. *Good Hope* from England to Cape Colony has been watched with great interest, an interest partly due to the honor thus paid Mr. Chamberlain in having, in deference to the wishes of His Majesty King Edward, a special man-of-war set apart for his voyage, but largely also—and especially in naval and engineering circles—to the great curiosity as to what would be the behavior of a brand-new ship fitted with new and (except on contractor's trials) untried machinery, with Belleville boilers, and, above all, with an engine-room staff nearly the whole of whom were absolutely strange to the ship, and very many of whom were young and inexperienced artificers and stokers.

Let us glance for a moment at the composition of this engine-room complement, and compare it with the staff that carried out the contractor's trials. The facts are given in the following table:

Commission complement.	Contractor's trials.
1 fleet engineer,	2 chief engineers,
2 engineers,	3 chief engine-room artificers,
4 assistant engineers,	16 engine-room artificers,
2 artificer engineers,	32 chief stokers,
3 chief engine-room artificers,	48 leading stokers,
20 engine-room artificers,	250 stokers,
10 chief stokers,	47 contractor's engineers,
23 leading stokers, first class,	24 apprentices (fitters),
10 leading stokers, second class,	4 boilermakers,
211 stokers, and stokers, second class.	4 apprentices (boilermakers),
	4 laborers,
	4 foremen.
286	438

On the day of sailing the commission complement was increased by the loan of six young and inexperienced engine-room artificers, who were "lent" for training, bringing the total available engine-room staff up to 292, as against 438 employed on the ship's trials, a difference in numbers alone of 146. But it must be remembered that the naval ratings engaged on the trials were mostly experienced, and that the contractor's men were all acquainted with, and employed on, the building and erecting of the machinery and boilers; and, further, that many were experienced sea-going engineers, holding certificates as such. The task then set the ship's staff of working the ship out to Durban at a speed of 17 knots (which was the speed ordered), stopping only at Suez and Zanzibar for coal, was by no means a light one.

The start was made from Portsmouth on the afternoon of November 25, when twenty-seven of the forty-three boilers fitted were lighted up; and, in view of possible trouble arising with the evaporators, in addition to 150 tons of fresh water carried in the reserve-feed tanks, a further supply of 279 tons was taken in at Portsmouth and carried between the double bottoms. Directly Spithead was passed the engines were worked up to 85 revolutions, corresponding to a speed of slightly over 17 knots. A few nickel rings at generator joints of the boilers gave a little trouble at first by leaking; as these gave out the boilers were promptly shut off, the elements lifted, new nickel rings put in, and the boilers relighted and connected to the engines.

"Dirty" weather was experienced next day in the Bay of Biscay, with a moderately heavy sea, causing the ship to knock about a good deal and take a lot of water on board, while the propelling engines raced at times. Many of the officers and ship's company were sea-sick, the stokers in the boiler rooms being at times practically of no use on this account. The engines had to be eased down two or three times during the day in order to secure a lower boom and one of the seaboats, both in danger of being swept away by the sea. On the second day out (November 27) the weather improved somewhat, and at 1 P. M. the

revolutions were increased to 88, so as to give a speed of about 18 knots.

Next day (November 28) a routine was commenced and continued throughout the voyage of lighting up a fresh group of boilers and letting a corresponding number die out in order not only to keep the boilers alight in proximity to the coal, but at the same time to have a staff of day men employed in making good minor defects which arose in boilers that had been steamed, sweeping tubes, &c., so as to prepare these boilers for again lighting up. This was found to answer very well, and it seemed likely that with assistance from the deck hands, which was being given, the ship could have been steamed continuously at this speed of about 18 knots.

Everything continued to go well with the machinery and boilers till Sunday, November 30, when the ship was nearing Malta; the starboard intermediate cylinder crankhead brasses then showed signs of heating and of slackness, the latter, no doubt, being due to the bad weather through which the ship had come, causing her to knock about somewhat and the engines to race. At 8 P. M. (off Malta) it was decided to stop the starboard engine and examine the brasses, continuing with the port engine alone. This was done, and on opening out the crankhead it was seen that the metal had run and the crankpin had been somewhat roughened up and scored; the spare brasses were therefore requisitioned and fitted, and the crankpin smooth filed and rubbed over with an oil stone, the work being carried out and the engine restarted in a little over 30 hours—no mean performence when it is considered that the crankpin is 24 inches in diameter by 30 inches long, and that the brasses weigh between 5 cwt. and 6 cwt.; all manipulation of them requiring blocks and tackle.

On December 2 and 3 each engine was stopped alternately for a short period to make slight readjustment of crank or crosshead brasses, as they began to wear, and at noon on the 3d the revolutions were reduced to 55 (11 knots) so as to enter Port Said at daylight next morning, which was done.

A table showing particulars of the run from Portsmouth till the engine speed was reduced is given herewith:

FROM PORTSMOUTH TO PORT SAID.

Date.	Average revolutions.	Average speed.	Distance run.	Total coal burned.		Indicated horsepower.	Coal per I.H.P. Engines.	Coal per I.H.P. for all purposes.	Deck hands employed.	
									Trimming.	As stokers, messengers, sweepers, &c.
		knots.	*knots.*	*tons.*	*cwt.*		*lbs.*	*lbs.*		
Nov. 25, 5 P. M. to 8 P. M.	83	17.3	52	33	0	Not taken.			10	13
Nov. 26 to noon	82	16.4	266	166	10	8,462	2.65	2.9	10	16
Nov. 27 to noon	82	15.2	356	238	5	11,273	2.18	2.43	20	16
Nov. 28 to noon	88	18.1	430	286	15	10,328	2.37	2.56	49	16
Nov. 29 to noon	88	18.8	440	282	0	10,639	2.3	2.48	49	16
Nov. 30 to noon	88	18.5	433	282	0	10,328	2.27	2.55	49	16
Dec. 1 to noon	87*	12.4	292	177	0	10,620	2.12	2.4	49	16
Dec. 2 to noon	75†	12	282	146	5	Not taken.			49	16
Dec. 3 to noon	75‡	15	354	187	0	Not taken.			49	16

* Starboard engine stopped at 8 P. M. preceding night. Port engine only afterwards.
† Port engine only at work.
‡ Starboard engine stopped 1 hour 50 minutes. Port engine stopped 50 minutes.

The ship entered the Suez Canal about noon on December 3, and reached Suez, making fast to a buoy between 9 and 10 o'clock on the morning of December 5, where coaling work was at once commenced on deck, and 2,000 tons shipped by 8 o'clock next evening. Down below opportunity was taken to examine and refit both intermediate-pressure crankheads, adjust crossheads and examine cylinders, air pumps and other parts of the machinery as far as possible, it being decided to keep the ship at Suez till daylight on December 8, to enable this to be done, thus giving about 68 hours for overhaul after a run of more than 3,100 miles.

At 6.30 A. M. on Monday, December 8, the ship sailed for Zanzibar, distant another 3,000 miles, and without any other port of call *en route*. Twenty-eight boilers were alight, and the engines worked up to 17-knot speed during the forenoon, everything

going most satisfactorily; the bearing that had previously given trouble showed no signs whatever of heating, and worked smoothly.

The heat of the Red Sea soon made itself felt in the stokeholds, though the temperature on deck was not excessive, averaging, as it did, only about 84 degrees in the shade; still, in spite of wind sails to carry air below (the ship has no cowls) and the stokehold fan engines being at work, the stokers found the work very arduous, but stuck well to it and kept up the revolutions.

About noon on the 11th H. M. S. *Perseus* was met in the Red Sea, near Aden, and communicated with, the engines being stopped for about an hour or so, afterwards proceeding at 85 revolutions, as before.

Things continued to go excellently till Saturday evening, December 13, when, unluckily, a bilge suction in the starboard engine-room choked, which caused the crank-pits on that side to be flushed with water. This water washed the oil out of the starboard intermediate-pressure crankhead brasses, causing them in a few moments to heat up, and the engine had to be eased to cool the brasses and crank pin down again. This only took a short time; but, unfortunately, the heating caused the metal to spread a bit and wipe over the oil ways, so that the bearing required very careful watching and plenty of lubrication. The ship duly arrived off Mombasa at daylight on the 15th, and transshipped Mr. and Mrs. Chamberlain and staff to H. M. S. *Forte*, whence they proceeded up the Uganda Railway, whilst the *Good Hope* continued her voyage to Zanzibar, where she duly arrived at six o'clock the same evening, the starboard engine being run between Mombasa and Zanzibar at 75, and the port at 85, revolutions, giving an average speed of about 16 knots.

The net steaming time for the distance logged of 2,849 miles between Suez and Zanzibar was 170.5 hours, which works out to an average speed of 16.7 knots. Particulars of this part of the passage are tabulated:

FROM SUEZ TO ZANZIBAR.

Date.	Average revolutions.	Average speed.	Distance run.	Total coal burned.		Indicated horsepower.	Coal per I.H.P. Engines.	Coal per I.H.P. for all purposes.	Deck hands employed.	
									Trimming.	As stokers, messengers, sweepers, &c.
	Variations	*knots.*	*knots.*	*tons.*	*cwt.*		*lbs.*	*lbs.*		
Dec. 8, 7 A. M. to noon.....	85	...	...	47	19	8,960	2.25	2.5	8	19
Dec. 9 to noon...	85	17.1	400	248	17	8,585	2.4	2.67	16	19
Dec. 10 to noon...	85	17	403	244	2	9,116	2.2	2.45	20	19
Dec. 11 to noon...	85	17	403	263	0	8,252	2.44	2.78	20	19
Dec. 12 to noon...	85	17	383	245	0	8,448	2.54	2.87	28	19
Dec. 13 to noon...	85	17	407	265	1	8,650	2.43	2.76	28	19
Dec. 14 to noon..	85	16.7	407	258	2	8,418	2.55	2.88	64	19
Dec. 15 to 6 P. M.	Port 85 Star'd 75	15.6	446	316	7	8,141	2.34	2.68	64	19

NOTE.—Time altered daily. Total number of hours making good distance = 170.5.

Information having been received at Mombasa from Natal that it was the desire of the people there that Mr. Chamberlain, instead of arriving on December 22 and immediately before Christmas, should reach Durban by daylight on the 26th, a stay of six days was made at Zanzibar—viz: from the evening of Monday the 15th to Sunday, December 21, during which period the ship was again coaled, 1,880 tons being shipped, and opportunity was taken in the engine rooms to re-examine and overhaul the starboard intermediate bearing, and to adjust other cranks and crossheads by taking off the leads and reducing the liners as necessary. Some of the main cylinders and slides were also looked at, and, as far as could be seen, were all working up nicely to a good smooth surface; indeed, they looked very well. Small defects to auxiliary engines and boilers were also rectified, the ship starting again on the last stage of her journey—viz: Zanzibar to Durban—at a speed of 15 knots, the distance between these ports being 1,600 miles. For this purpose twenty boilers

were lit up, and during the earlier part of the trip the starboard engine was again kept going at a slower speed than the port, till noon on Christmas Day, when, having lighted up seven more boilers, the speed of both engines was worked up to 17 knots or 85 revolutions, the ship finally reaching Durban at daylight next morning, in accordance with arrangements made by telegram at Mombasa, thus finishing up the voyage at 17 knots—the same speed as at the commencement; the only engine-room defect of any importance being that two pairs of crankpin brasses required remetalling and refitting. Particulars of the run from Zanzibar to Durban are shown.

FROM ZANZIBAR TO DURBAN.

Date.	Average revolutions.	Average speed.	Distance run.	Total coal burned.	Indicated horsepower.	Coal per I.H.P. Engines.	Coal per I.H.P. for all purposes.	Deck hands employed.	
								Trimming.	As stokers, messengers, sweepers, &c.
		knots.	*knots.*	*tons. cwt.*		*lbs.*	*lbs.*		
Dec. 21, 7.30 P. M. to noon Dec. 22	Star'd, 63 Port, 75	15.2	251	120 0	5,229	2.46	2.99	Nil.	19
Dec. 23 noon	Star'd, 73 to 50 Port, 75	13.9	334.5	171 1	6,053	2.22	2.56	Nil.	19
Dec. 24 noon	Star'd, 60 to 75 Port, 75	14	340	168 1	6,303	2.24	2.75	Nil.	19
Dec. 25 noon	Star'd, 76 Port, 79	14.73	359	196 0	6,812	2.46	2.8	Nil.	19
Dec. 26 to 6 A. M.,	85	17	306	196 0	8,650	2.33	2.59	Nil.	19

The boilers throughout the whole trip worked excellently, small defects, as before explained, being undertaken by a strong staff of men in the daytime in those boilers not alight. Taking into account the fact that during the greater portion of the voy-

age, as a rule, between forty and fifty auxiliary engines were almost continuously in use, in addition to the main engines; and seeing that the average coal consumption over the whole passage worked out to approximately 2.66 pounds per indicated horse-power per hour for all purposes, it would not appear that the Belleville boilers were unduly expensive. The air blowers were kept in use most of the time, not so much with a view to maintaining steam, as because it was found they considerably reduced the smoke made.

As regards water consumption, no accurate measured record could be kept; but on all occasions it was found that with the ship's evaporators working on the "closed exhaust," sufficient water could be made for drinking purposes and to make up the boiler loss, and at the same time leave a large surplus of exhaust steam for doing useful work in the L.P. receivers of the main engines, the extra 279 tons of fresh water taken in the double bottoms at Portsmouth being still intact on arrival at Durban.

COMPARATIVE PERFORMANCE.

H. M. S. "GOOD HOPE" WITH U. S. S. "COLUMBIA."

The foregoing article will be read with exceeding interest by all interested in what transpires beneath the protective decks of modern war ships. The journey of the *Good Hope* will give conclusive evidence as to the actual number of men necessary to operate the motive power of a modern cruiser when steaming for a continuous period at a higher rate than cruising speed. It will likewise shed considerable light upon the question as to the economy and efficiency of an installation of Belleville boilers when subjected to somewhat severe sea conditions.

There have been few men-of-war which have been called upon in time of peace to do harder work than that exacted of H. M. S. *Good Hope*. A careful study of the performance of the cruiser will likewise give some idea of the sustained sea speeds that can be expected of modern cruisers under the actual conditions that prevail on board vessels in commission.

In analyzing the performance of the *Good Hope* on the voyage

between Portsmouth, England, and Durban, South Africa, it is mete to note the work done by the U. S. S. *Columbia* during her full-speed trial across the Atlantic in 1895.

The comparative results would indicate that the performance of the U. S. S. *Columbia* has not been surpassed by H. M. S. *Good Hope*—although the latter vessel is one of the latest examples of naval construction—in fact, a warship lately commissioned and one launched seven years after the American cruiser with which she is compared.

The trip of the *Good Hope* was probably intended by the Admiralty to prove a record performance. It was certainly so regarded by the naval world. To carry the Hon. Joseph Chamberlain as a Special Commissioner, the *Good Hope* was presumably selected by reason of the fact that she is a representative of the speediest class of large ships of the British Navy. It was rather a good omen that she bore the name she did.

As it was expected that the ship would make a record-breaking journey, her performance was closely watched by naval architects, marine engineers, shipbuilders and naval officers. It was also well understood that her installation of Belleville boilers was on trial. In view of the important mission upon which the ship was sent, it can also be presumed that a trained and experienced force was detailed for the stokehold, so that the boilers received the best possible care and attention. The number of men detailed for duty in the fire rooms showed that at least an adequate complement had been provided.

There was also a good sized quota of men in all the higher ratings, so that particular attention might be given to the operation of all the auxiliaries in both engine and fire rooms. This complement, however, was not nearly as large as that deemed necessary by the builders of the vessel when conducting the official tests demanded by the government's contract.

The voyage of the *Good Hope* was via the Mediterranean, Suez Canal, and then down the African coast to Durban. As the problem given the ship's complement was to steam the vessel at a regular speed of 17 knots, the route through the canal, although somewhat longer than that around the Cape, favored the ship,

since it permitted several stops to be made, and probably insured for the ship easier weather. While stopping at Suez and Zanzibar there were opportunities to make minor repairs and to secure fresh water. In other ways the journey through the Suez Canal assisted in diminishing the labor and strain of the engineers' force.

The start was made from Portsmouth, England, November 25, 1902, twenty-seven of the forty-three Belleville boilers being used to secure the required power necessary for making the prescribed speed. Heavy weather was only experienced in the Bay of Biscay, and then it was necessary to slow down for only a few hours. Afterwards the regular routine was carried on, and this routine has been described in the text of the article. It will be noted that occasional trouble occurred in the engine room.

Reverting to the voyage of the U. S. S. *Columbia* from Southampton to New York, that vessel steamed out of the English port with fires in all her furnaces, the boiler installation consisting of eight double-ended Scotch boilers, four furnaces being at each end. At no time were fires hauled in any furnace. The vessel ran at full speed during the entire voyage, except for four hours when the ship was slowed down on account of fog.

The *Columbia* was ordered to proceed to New York, using all boilers under natural draft, and to use all three sets of engines. For the first two days the limit of coal consumption was not allowed to exceed 200 tons per day. During the remaining four days the limit was not allowed to exceed 225 tons per day. The average coal consumption during the trip was about 212 tons per day.

It is exceedingly regrettable that the *Columbia* was not run under forced draft for a day or two after leaving Southampton. It would then have been possible, by reason of the arrangement of the ship's bunkers, to have supplied the furnaces with all the coal that could have been burned. When it was suggested, near the end of the run, to use forced draft, it was found that it would not be possible under such conditions, due to the fact that all the bunkers in proximity to the firerooms had been emptied, and therefore sufficient coal could not be fed to the

boilers when the consumption was greatly increased. The experience of the *Columbia* in this respect conclusively shows, that the question of rapidly getting coal out of the bunkers is one of military importance, and that more attention should be given to the subject.

The following comparative statement as to the performance of H. M. S. *Good Hope* and U. S. S. *Columbia* will be of interest to all the readers of the JOURNAL in noting in some respects the progress that has been made in naval engineering design during the past five years.

The records of the two vessels are also shown in tabular form.

TABLE OF PERFORMANCES OF H. M. S. *GOOD HOPE* AND U. S. S. *COLUMBIA*.

.....	H. M. S. *Good Hope*, Nov. 25, Dec. 26, 1902.				U.S.S. *Columbia*, July 26, Aug. 2, 1895.	
	Best day's run.	Portsmouth to Port Said.	Suez to Zanzibar.	Zanzibar to Durban.	Best day's run.	Southampton to New York.
Total knots run.....	.....	2,905	2,849	1,590	.....	3,090
Day's run, knots.....	440	376	401	356.5	462	442
Speed, average knots per hour.....	18.8	15.7	16.7	14.85	19.25	18.41
Days, straightaway.....	.....	7.73	7.1	4.46	.....	6.98
I.H.P., main engines.....	10,639	10,175	8,571	6,600	10,554	9,576
aux. machinery.....	.....	.....	.....	.....	.....	140
Tons of coal per day, all purposes.....	282	221	254	178	230	212
Tons of coal per day for auxiliaries	.....	.....	.....	.....	.....	11.33
Pounds of coal per I.H.P. per hour, main engines....	2.3	2.31	2.59	2.34	1.93	1.95
Pounds of coal per I.H.P. per hour for all purposes..	2.48	2.55	2.69	2.74	2.03	2.07
Distance run per ton of coal, knots.....	1.56	1.70	1.58	2	2	2.08
Pounds of coal consumed per knot run.....	1,435	1,316	1,419	1,119	1,115	1,074
Pounds of coal used per ton of displacement.....	2.38	2.24	2.42	1.90	3.6	3.5
Estimated relative coal consumption per 1,000 tons displacement at 10 knots..	$D^{\frac{2}{3}} S^3$		9.49	.....		8.98

GENERAL FEATURES OF BOTH SHIPS.

	H. M. S. *Good Hope.*	U. S. S. *Columbia.*
Displacement, tons,	14,100	7,350
Length,	500	411.5
Breadth (load line),	71	58.3
Draught, mean,	26.5	22.4
TRIAL FIGURES.		
Knots speed,	23.05	22.8
R. P. M.,	122.4	131.72
I.H.P.,	31,088	18,509.2
Pressure,	...	145
Boilers,	43 Belleville	8 Scotch
Boilers in use,	27	all

The following deductions can be made:

1. *Columbia's* average speed per day exceeds that of *Good Hope's* maximum.

2. *Columbia's* daily run exceeds *Good Hope.*

3. *Columbia's* maximum speed per hour exceeds *Good Hope.*

4. *Columbia's* average speed per hour is greater than *Good Hope.*

5. *Columbia's* average horsepower is greater than *Good Hope.*

6. *Columbia's* consumption of coal per horsepower is less than *Good Hope's.*

7. *Columbia's* coal consumption per one thousand tons of displacement at 10 knots is less than that of *Good Hope.*

In making comparison between the *Good Hope* and the *Columbia*, the respective displacement of the two ships should be considered. The facts should also be remembered, however, that the *Columbia* had a much smaller complement of men in her firerooms than did the *Good Hope* in developing practically the same horsepower. As all fires were lighted in the furnaces of the *Columbia*, the fire-room conditions of that vessel ought to have been much more severe.

To accomplish the satisfactory results noted for the U. S. ship it may prove interesting to compare the working personnel of the engineer's force.

H. M. S.	U. S. S.
1 fleet engineer,	1 chief engineer,
2 engineers,	1 passed assistant engineer,
4 assistant engineers,	2 assistant engineers,
2 artificer engineers,	2 naval cadets as engineers,
3 chief engine-room artificers,	12 machinists, chief and 1st class,
20 engine-room artificers,	3 boilermakers,
10 chief stokers,	1 blacksmith,
23 leading stokers, 1st class,	8 water tenders,
10 leading stokers, 2d class,	15 oilers,
211 stokers, 8 stokers, 2d class,	67 firemen, 1st and 2d class,
6 engine-room artificers for instruction,	78 coal passers,
83 seamen, used as coal passers, stokers, tube sweepers, etc.,	12 seamen detailed from deck,
375 total engine-room complement H. M. S.	202 total engine-room complement U. S. S.

The above comparison ought to give some pretty conclusive evidence as to whether or not there is an overcrowding of men in the fire and engine rooms of the United States warships. It will be observed that the horsepowers developed on the two ships were nearly the same, and yet 83 men from the deck were detailed for duty in the stokeholds of the *Good Hope*, while only 12 of the deck force were called upon for fire-room work during the run of the *Columbia*.—[THE EDITOR.]

THE DESTRUCTION OF THE STEAMSHIP *PROGRESO*.

EFFECT OF EXPLOSION OF OIL FUEL.

By Leo Morgan, Member.

Having been requested by the Council of the American Society of Naval Engineers to personally inquire into and to record the nature and cause of the terrific explosion that occurred on the Steamship *Progreso*, the writer has given much time and study in looking into the matter.

The destruction of this vessel at the works of the Fulton Engineering and Shipbuilding Company, San Francisco, on the morning of December 3d, 1902, has received more than passing interest. The use of crude oil for marine purposes had received a great impetus on the Pacific Coast, and, lamentable as the accident was, there is no doubt but that the destruction of this tank steamer will cause increased attention to be given to the question of constructing the stowage tanks so that an accident of this kind will be less likely to take place in the future.

The *Progreso*, formerly known as the *Wells City*, was an iron cargo boat of 1,919 gross tons, built in Sunderland, England, in 1884. Her length was 270 feet; beam, 36 feet, and had a depth of hold of 23.5 feet.

Her engine was of the triple-expansion type, the cylinders being 21 inches, 36 inches and 57 inches, in diameter, with a stroke of 36 inches, and a double-ended return-tubular boiler of the Scotch type, 16 feet long and 14 feet in diameter. The boiler was built in 1902 by the Fulton Engineering and Shipbuilding Company, under the supervision of Lloyds surveyors, and was tested by the U. S. local inspectors to a hydraulic pressure of 263 pounds, and was allowed a working steam pressure of 175 pounds.

The vessel was transferred to the American flag in 1888, and

at the time of the explosion was owned by the *Progreso* Steamship Company. For about six months previous to her destruction, the vessel had been undergoing alterations necessary for fitting her as an oil carrier and oil burner, which work was practically completed when the explosion occurred on the morning of December 3, 1902.

The vessel was provided with five oil-cargo tanks, having a total capacity of 16,255 barrels and one oil-fuel tank of 1,940 barrels capacity. The oil-fuel tank, 18 feet in length, was built into the vessel, and was located just forward of a water-filled cofferdam, 24 inches long, the after bulkhead of which was 9 feet 2 inches forward of the forward end of the boiler. The 'tween decks constitutes the top of the tank; the 'thwartship bulkheads extending up to this deck. From the top of the oil-fuel tank an expansion tank, fitted with a hatch 16 inches wide by 42 inches long, extends to the main deck, while for ventilation two $1\frac{1}{4}$-inch pipes were carried from the top of the tank to the same level. The cargo tanks were fitted in a similar manner with expansion trunks and vent pipes.

On December 1, 1902, about 400 barrels of oil, supplied by the Union Oil Company, were pumped from the tug *Sea Rover* into the oil-fuel tank of the *Progreso*, and preparation was made for making a dock trial. This trial was made on December 2d, and orders were given to have steam ready for a trial on the Bay by 2 P. M. on December 3d. The fires were lighted at 7·30 A. M. on that date, and at 9 A. M. the steam gauge on the boiler registered between 40 and 50 pounds. At 9·20 the explosion occurred, forcing, according to the U. S. local inspectors' report, the cofferdam bulkheads aft, the deck over the fuel tank upwards, and the ship's sides outward, thus breaking the vessel in two at this point, and caused the death of twelve persons together with severely injuring ten others.

At the time of the explosion the fuel tank contained between 300 and 400 barrels of oil, probably about one-sixth of its volume, thus leaving a large space in which gas could collect and under proper conditions become a destructive agent. From the care taken to protect the oil from the heat of the boilers it is not at

all likely that the explosion was in any way due to this cause, especially as the temperature in the fire room was very much lower than on the preceding day, and the only apparent solution of the question is that the gas must have been escaping from the tank and was ignited by being brought in contact with a flame.

From the testimony taken during the investigation made by the U. S. local inspectors of hulls and boilers, Messrs. C. F. Bolles and J. K. Bulger, into the cause of the explosion, it was shown by analysis of samples of the oil taken from the tanks of the tug *Sea Rover* on the day of the explosion that the oil placed in the fuel tank of the *Progreso* contained 3½ per cent. of a low-grade gasoline and 6½ per cent. of other distillates, that it was 22.8 degrees (Baumé) gravity, flashed at from 85 degrees to 101 degrees Fahrenheit and burned at 138 degrees Fahrenheit, and was, in their opinion, a dangerous oil for storage as fuel oil for steam vessels.

The testimony further showed that lighted forges were in use in the 'tween decks and hot rivets had been driven into the hull in the vicinity of the fuel tank on the morning of the explosion.

They also found that there were many electric wires throughout the vessel for construction purposes, which might possibly have contributed to the disaster.

They were unable, however, from the testimony taken and examination made of the hull, to decide how the gas was ignited, and gave it as their opinion that the wreck of the *Progreso* was caused by an explosion of gas which had accumulated in the oil-fuel tank of the vessel, generated from the fuel oil therein and which was ignited in some unknown way. That the oil had been mixed with a lighter one in order to make it flow easily seems to be an established fact, and that the mixture was dangerous in character was fully demonstrated by the extent of the damage done, but how that escaping gas was ignited has not yet been determined.

At the coroner's inquest, held on January 31, 1903, over the remains of eight of the victims of this disaster, the only new evidence of importance offered was an attempt to establish the fact that a stanchion was being fitted between the top of the fuel-oil

tank and the deck above, and that possibly the man in drilling through the top of the tank made a vent for the gas, which, coming in contact with the flame of his candle, produced the explosion. As the man who was supposed to be doing the drilling is numbered among the victims of the disaster, and the fitting of the stanchion was disputed, the jury was not able to arrive at anything conclusive on the subject and rendered a verdict as follows: "We find that the actual cause of the explosion on the steamer *Progreso* is unknown. We further find that gross carelessness prevailed in using an oil for fuel which had not been properly tested."

In conclusion, I wish to acknowledge my indebtedness to Boiler Inspector J. K. Bulger for information obtained and to Mr. J. Spiers, Jr., the general manager of the Fulton Iron Works.

OBITUARY.

DAVID PHILLIPS JONES.

The death, on Friday, January 30th, of Chief Engineer David Phillips Jones, U. S. Navy, retired, removed one of the prominent figures of the old Engineer Corps of the Navy and a man who had always been, both on the active and retired list, a fine representative of the service wherever placed. Mr. Jones was born in Philadelphia, March 15th, 1840, so that he lacked less than two months of being sixty-three years of age at the time of his death. He entered the Navy March 25th, 1862, and passed through the various grades in due course, finally, after the long stagnation in the promotion of passed assistant engineers, reaching the grade of chief engineer in January, 1889. He was retired for physical disability in June, 1892. During the civil war he was continuously in active service, and took part in several of the prominent engagements.

He was noted for his ability as a draftsman and designer, so that he was assigned to duty several times in the Bureau of Steam Engineering, where he rendered excellent service. His most important work, however, was his part in the organization and development of the four-year course for cadet engineers at the naval school. There had been for several years a two-year course for engineering students, but the progressive officers of the Engineer Corps felt that for the best results the course for the young engineers should be, as far as practicable, the same as for the young line officers, differentiating only in the technical sides of the two professions. The first class under the four-year course entered the Naval Academy in 1874, and Mr. Jones was ordered to the academy at that time as one of the instructors. Besides his natural interest in the success of the plan which he had been instrumental in starting, he was always very fond of young men and had a great attraction for them, so that it would probably have been difficult to find anywhere one who came nearer to being the ideal instructor. He was on duty at Annapolis con-

tinuously for five years, during which time all of the cadet engineers who pursued the separate course to its completion entered. Among those who were his students, and who have since become eminent outside of the Navy, may be mentioned Professor Hollis, of Harvard; Professor Spangler, of the University of Pennsylvania, and Professor Cooley, of Ann Arbor, besides a number of others who are filling important positions in manufacturing establishments, but who are not, perhaps, so well known.

The work which fell upon the instructors in the engineering course at this time was peculiarly difficult as compared with existing conditions, for the reason that there were few, if any, satisfactory text-books, and the instruction had to be given largely by lectures prepared by the instructors. In this work Mr. Jones took a most important part. Besides the influence which he exerted upon the young men under his instruction in the class room, he and his charming wife, who was Miss Nellie Kellogg, of Erie, Pa., made their house a home for the young engineers, although it was not limited to them, and a great many of the young line officers were also counted among their personal friends. The benefit of the home influence thus exerted over young men at the formative period of their lives can hardly be over-estimated, and, while they may not at the time have fully appreciated it, those who enjoyed this privilege have, as they grew older, appreciated how greatly they were indebted to Mr. Jones, and their affection for him was very marked. To them he was always "Uncle Davy."

It was largely due to Mr. Jones that Hon. W. S. Shallenberger, now second assistant postmaster general, but then a member of Congress, introduced and had passed a bill providing for the detail of engineer officers to technical schools, and from these details have resulted the mechanical engineering departments of some of our prominent colleges, while, as mentioned above, a number of his boys have become leading professors of engineering.

After his retirement Mr. Jones devoted himself to looking after his private interests and to practice as a consulting engineer, at first in Chicago and later in Pittsburg. During the war

with Spain he was assigned to duty as chief steel inspector in the Pittsburg district, and on the conclusion of the war he opened an office as a consulting engineer and was enjoying a large practice at the time of his death.

Mr. Jones was celebrated throughout the Navy and wherever he was known for his remarkable skill as a raconteur. In this respect he had few equals, for, in addition to his ability to bring out the point of a good story, he had remarkable histrionic talent which added immensely to the effectiveness of his narration. He was also a past master in the art of giving a dinner, and those who were fortunate enough to be his guests knew that a rare treat was in store for them, both for the mind and the palate. His wit was remarkably keen but kindly, and he was one of the founders of the Alibi Club in Washington, known for the wit and brilliancy of its members. He was without doubt one of the most popular officers who has ever been in the Navy, both with brother officers and with people in civil life with whom he was associated.

After his retirement from the Navy he served for a time on the staff of the Governor of Kansas, with the rank of colonel, so that of late years he was generally called Colonel Jones. He leaves an only daughter, Miss Anita K. Jones. In September of last year he was married to Miss Olive Harton, of Pittsburg. Mr. Jones has left a record for ability in his profession, faithful performance of duty, and the maintenance of the highest possible standard as an officer of which any one could be proud, but beyond this his genial personality and helping hand for younger men has made a place in the hearts of those who were his friends and pupils which will endure until they themselves lay down their active work.

Funeral services were held in Pittsburg on Sunday afternoon and the body was taken to Erie, Pa., for interment on Monday, February 2d. The pallbearers were Captain W. B. Brooks, U. S. Navy; Messrs. Walter Scott and T. J. Hemphill, of Erie, and Messrs. Henry Spooner, Asa M. Mattice and Walter M. McFarland, the last three, former officers of the engineer corps of the Navy. A detail from the *Michigan* acted as body bearers.—"Army and Navy Register," February 14, 1903.

ASSOCIATION NOTES.

AMERICAN SOCIETY OF NAVAL ENGINEERS.

The annual meeting of the Society for the election of officers for the ensuing year, and for the presentation of the Annual Report of the Secretary-Treasurer, was held at the Bureau of Steam Engineering, Navy Department, Washington, D. C., December 27, 1902.

The election of officers resulted as follows:

President, Lieutenant Commander W. M. Parks, U. S. N.

Secretary-Treasurer, Lieutenant Commander J. R. Edwards, U. S. N.

Council.—Captain George W. Baird, U. S. N.; Lieutenant Commander F. J. Schell, U. S. N.; Lieutenant C. W. Dyson, U. S. N.

The following financial statement was submitted by the Secretary-Treasurer:

Balance in bank January 1, 1902	$4,784.93
Cash and checks	222.13
Total	$5,007.06

RECEIPTS.

Annual dues	$2,248.50	
Back dues	360.00	
Advance dues	90.00	
Subscriptions to JOURNAL	542.19	
Sales	347.46	
Advertising	2,054.97	
Exchange and sundries	10.51	
Interest	98.83	
Total		$5,752.46

EXPENDITURES.

Printing JOURNAL, stationery, etc.	$3,296.94	
Engraver	354.54	
Salary, Secretary-Treasurer from December 15, 1901, to January 1, 1903	937.50	
Postage, expressage, etc.	63.51	
Commissions on advertisements	175.02	
Annual prize and medal	105.00	
Purchase of journals	63 62	
		4,996.13
Net gain for the year		756.33
Balance on hand January 1, 1903		5,763.39

The Council audited the accounts of the Secretary-Treasurer and found them correct.

C. W. DYSON, *Lieutenant, U. S. N.*,
Secretary-Treasurer.

C. W. RAE, *Captain, U. S. N.*,
President.